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ASTRONOMY

The World's Most Beautiful Astronomy Magazine

August 1973

Vol. 1, No. 1

HOUR OF THE MIDDAY NIGHT 4 by Jay M. Pasachoff	SKY ALMANAC 34 Perseid Meteor Shower Jupiter Venus Mercury Mars Saturn Comet Kohoutek by Terence Dickinson August Variable Star by R. Newton Mayall
STELLAR FRONTIERS 16 In Search of Planet X by Wm. Bruce Weaver	CONSTELLATION CLOSE-UP 42 Capricornus by Thomas C. Bretl
GAZER'S GAZETTE 20 Mystery Stars by R. Newton Mayall	Article Bibliographies 41 Contributor Policy 47
AUGUST STAR DOME 24 by John Harmon	
PHOTOGRAPHY IN ASTRONOMY 27 Optics for Astrophotography by John Sanford	

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Cover: (Harvard College Observatory photograph)

Using a highly specialized filter to isolate one element (five times ionized oxygen at a wavelength of 1032 angstroms) in the sun's innermost corona, Orbiting Solar Observatory VI provided this photograph showing various levels of intensity. Five times ionized oxygen is formed at a temperature of one million degrees Fahrenheit in the solar corona — about 62 miles above the sun's surface. Such information is only available from satellite observatories because the earth's atmosphere obscures light having as short a wavelength as five times ionized oxygen. From photographs like these which provide very clear information on one particular height in the solar atmosphere — by looking at only one small part of the corona's entire spectrum — astronomers are able to interpret the density, composition, structure and temperature of the sun. This and all Harvard College Observatory photographs in "Hour of the Midday Night", starting on page four, were supplied by Jay M. Pasachoff, Williams College.

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Application to mail at second class postage rates pending at Milwaukee, Wisc.

Send change of address to ASTRONOMY, Circulation Services, 1726 North 1st St., Milwaukee, Wisc. 53212. Allow six to eight weeks for address change to take effect.

Cover price, \$1.50. Subscription price: 1 year, \$12.00; 2 years, \$22.00; 3 years, \$30.00.

Postmaster: When undeliverable, send form 3547 to publisher.

Separations prepared by Graphics Unlimited, Inc.,
Butler, Wisconsin 53007

Printed by Quad/Graphics, Inc., Pewaukee,
Wisconsin 53072



HOUR OF THE MIDDAY NIGHT

by

Jay M. Pasachoff
Director, Hopkins Observatory

The sky grew dim as the dazzling crescent above, normally a full blazing orb, deepened. The equatorial air grew still and cool and an eerie half glow enshrouded the depths of Africa. As birds began to roost that eventful summer's midday, distant drums eloquently proclaimed the ancient fears of primitive tribal witch doctors.

All stood in awe, gazing toward the sky while the sun slowly vanished as though devoured by some occult force. Native rituals quickened, heart-throb drum beats grew intense and the mighty demon relinquished its seldom sought quarry, and all were saved.

The total eclipse of the sun had ended.

Although primitive African tribesmen might have reacted fearfully to the June 30, 1973 eclipse, professional astronomers who witnessed the event (being somewhat more sophisticated) were aware of the reasons why the moon momentarily blotted away the sun. In fact, they had

planned their activities many months prior to the event.

The positions of the sun, moon and earth essentially repeat with respect to each other every 18 years, 11-1/3 days. So the June 30 eclipse was much the same as one that took place in 1955. The primary difference was that the earth had rotated on its axis one-third of a turn farther than 1955, placing the eclipse in equatorial Africa.

The earth revolves around the sun every 365-1/4 days — we call that a year. At the same time, the moon rotates around the earth every 27-1/3 days — the origin of our measure of time called a "month". Once each month, when the moon is in the same general direction of the sky as the sun, the side facing us (away from the sun) appears dark. We call this the "new moon", and it is highest in the sky at noon.

Conversely, two weeks later, the moon will be on the side of the earth away from the sun and will be highest in our sky at midnight. Then the side we see is fully illuminated and the moon is "full".

But the moon's orbit is slightly inclined to the plane of the earth's orbit, and the sun, moon

The pearly-white color of the sun's corona at the instant of totality during a solar eclipse is a spectacle rarely matched in nature. Few who have witnessed a total eclipse would doubt the superstitious fears held by ancient civilizations as they viewed the apparent demise of their prime source of energy. (Photograph by Jay M. Pasachoff)

and earth don't always line up exactly. Usually the moon passes either a little above or below the line drawn through the earth and the sun. Every few months the alignment is a little better and we have the joy of an eclipse.

The earth's shadow is larger and longer than the moon's, of course, and can cover all the moon during a lunar eclipse. Thus if you are on the part of the earth where the moon is above the horizon, you can see the lunar eclipse. Although in the past lunar eclipses have been used to prove that the earth is round, because its shadow is round, or to discover the thermal properties of lunar rocks, in these days of Apollo exploration lunar eclipses are ordinary things.

But solar eclipses are still among the rarest and most valuable phenomena we know. The moon's shadow barely touches the earth, and it is only an elite few who can see the sun blotted out at noon within the narrow band where the eclipse is total. It is a celestial accident for us that the moon, which is 400 times smaller across than the sun, is also 400 times closer. As a result, they appear to cover (subtend) the same angle in the sky. Thus, once every year or so, when the sun, moon and earth are in a straight line, the bright surface of the sun that we see every day, the photosphere, is precisely covered by the moon. This is a total eclipse, and its duration (as long as seven minutes) is called the length of totality.

The length of time that totality lasts varies from eclipse to eclipse. The moon's orbit is somewhat eccentric, which brings the moon at times closer or farther from the earth. This causes the moon's diameter to appear slightly larger than that of the sun, and sometimes smaller. When the moon's diameter is greatest, and it can be as much as 10 percent larger than the sun, conditions are such that there is the possibility of a long eclipse. When the moon's diameter is smallest, it doesn't cover the photosphere entirely. In this instance it may pass in front of the sun and leave a circle of bright sunlight around it. This is called an annular eclipse. Annular eclipses and partial eclipses (when the moon covers only a part of the sun) are of little interest to astronomers. The solar photosphere is so brilliant that our sky remains too bright to see the faint outer layers of the sun.

But when a total eclipse occurs, things change drastically. Only if you are in the zone of totality does the sky grow completely dark as night. The time between first contact when the moon first touches the edge of the sun, to second contact, when it covers the sun entirely, takes about an hour. At the instant of second contact or totality, all becomes very dark. Animals act as

though night has come, and the pinkish chromosphere and prominences flash into view all around the sun. Within seconds, as the moon covers the chromosphere too, an even fainter halo appears around the sun. This pearly-white crown is called the "corona". The chromosphere, prominences and corona are laboratories in space where gases exist under very strange circumstances; the brief moments at total eclipses allow astronomers to study them best.

The apparent diameter of the moon projected in the sky is not the only variable that determines the length of an eclipse. The shadow of the moon sweeps across the face of the earth at the tremendous velocity of thousands of miles per hour. But the earth is also rotating in the same direction as the shadow. Earth spins fastest near the equator, where any given point must rotate 25,000 miles each day. It turns slowest near the poles, because the north and south poles are stationary and don't turn at all. So if an eclipse occurs near the equator at noontime, the earth can keep up with it relatively well, and totality is much longer. This, linked with the relative angular diameter of the moon and sun in the sky, determines the length of eclipses.

A total eclipse is the most spectacular sight known to man, for the most powerful source of energy in our lives is actually blotted out. But you have to travel to the zone of totality itself to appreciate it. Many people say, "I saw the eclipse. It was 99 percent total." But 99 percent doesn't count. The chromosphere is only one one-thousandth as bright as the everyday photosphere, so even if 99 percent of the photosphere is covered, the rest remains ten times brighter than the chromosphere. It is really the corona, a million times fainter than the photosphere and one ten-thousandth as bright as a 99 percent eclipse, that we want to see above all. So with eclipses, it is all or nothing; the "99 percent people" don't know what they are missing.

People who have seen a partial eclipse may be likened to those who have stood outside an opera house before opening night, watching the beautifully dressed people going in. All the preparations take place and the orchestra tunes up. But just as the opera is about to start, the partial eclipse viewer goes home. He may well be content with what he has seen, but in reality he has missed the entire show.

For he has missed a glorious sight and a chance to observe a strange celestial laboratory. The superhot conditions in the sun often cannot be met in earth-bound laboratories. So we are limited to observing the stars to find out how matter behaves under these conditions. However,

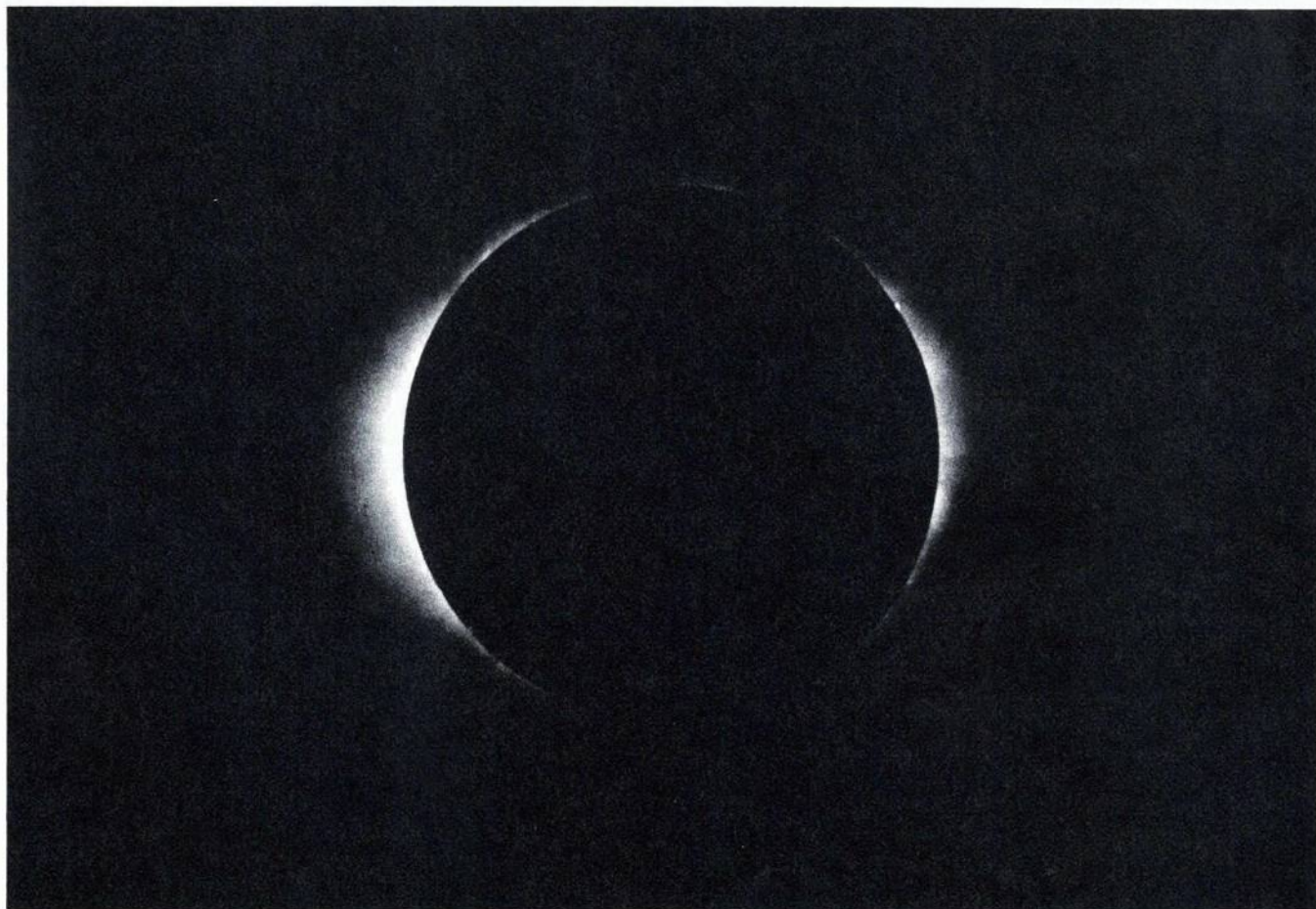
our sun, also a star, is so close to us (only 93 million miles away) that we can see details on its surface and layers around its edge. We cannot see this with any other star. Light from the sun reaches us in eight minutes; the next nearest star is four light-years away, over one hundred thousand times farther. What we learn from the sun tells us about other stars too, and understanding the sun may be the key to unlocking the universe.

As scientific techniques develop, and as we become able to observe the sun from balloons, airplanes, satellites and even the moon, we will be able to obtain new information about some aspects of the solar atmosphere without an eclipse. But this information is often supplementary to what we learn from eclipses. We still are not able to duplicate in any other way the observations that are made in the brief moments during totality. It will be many years before space techniques are sufficiently advanced to take over, and even when they are, eclipse expeditions are much less expensive than space experiments while still providing a substantial scientific return.

Composition of the Sun

The photosphere has an average temperature of 6000 degrees Centigrade, and covers the complicated nuclear furnace of the solar interior which cannot be studied directly. From the photosphere we receive all the light and heat that allows us to live on earth, that provided the energy now stored in fossil fuels underground, and that may become a direct, pollution-free source of energy in the future.

When you look at the spectrum of the photosphere (when its light is broken down into component colors using a prism or a diffraction grating), you see a giant rainbow with dark, vertical stripes across its length. These dark regions occurring at specific colors are called Fraunhofer absorption lines, after the scientist who discovered them in the early 19th century. Several thousand absorption lines are found in the solar spectrum, and each contains information about composition of the sun's elements or about the temperature of the sun, density of its gases, and velocities with which the gases are moving.



Photograph by Rob Duisberg

The sun's inner corona was photographed during the July 10, 1972 total solar eclipse visible from Prince Edward

Island in Canada. Note the small solar prominence at the upper right hand edge of the eclipse disk.

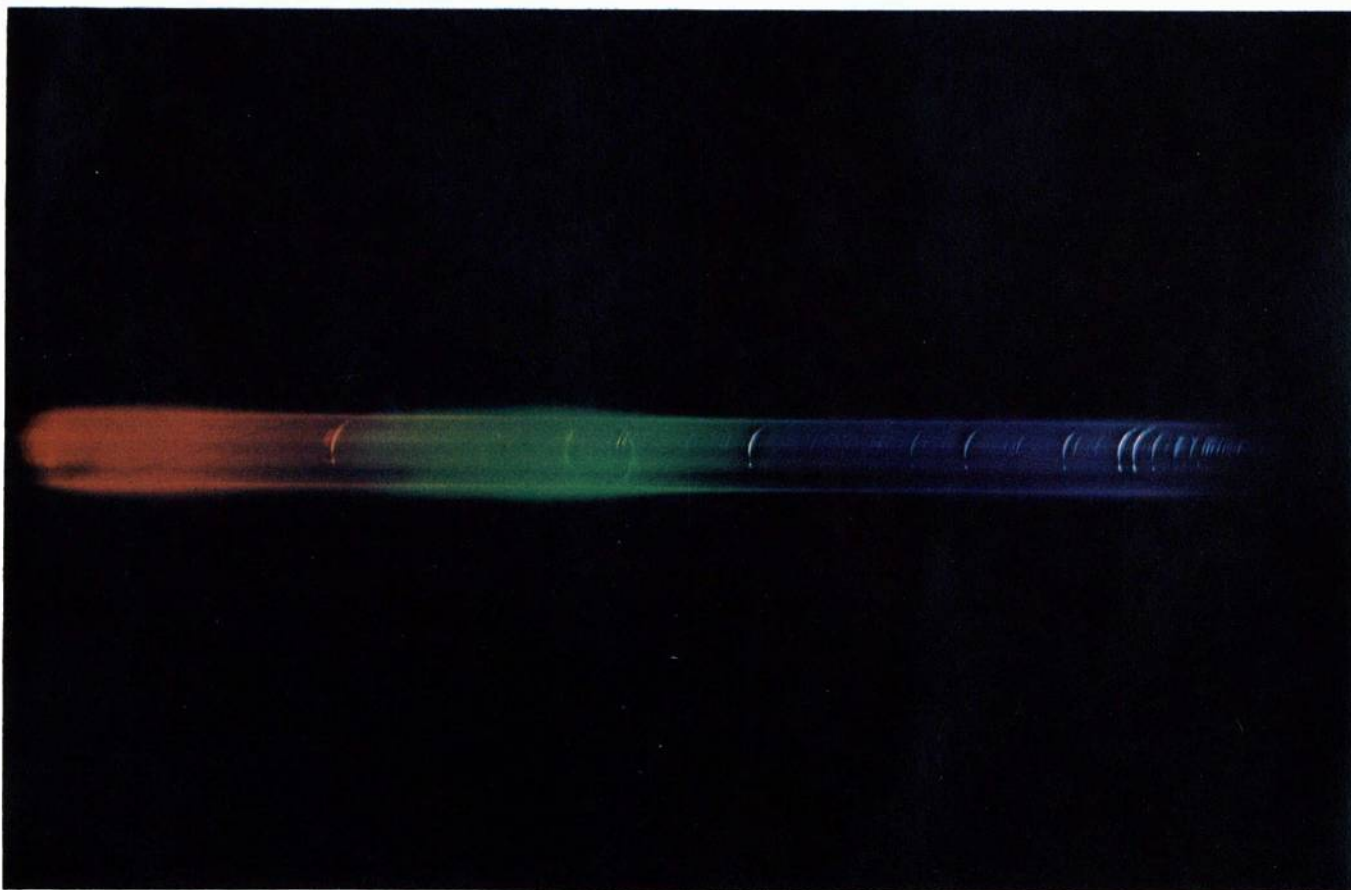
The light from the solar photosphere scatters in the earth's atmosphere causing our blue sky. At arm's length, hold your thumb so it covers the sun (you'll see solar astronomers doing this all the time to test the quality of the sky). Notice that even when you block out the sun there is a glow around your finger; you can tell where the sun had been. This means that it is too bright to see the chromosphere and corona. With a better quality sky, the sky would remain the same color blue right up to the edge of your thumb.

The chromosphere is hotter, and one-thousandth as bright as the photosphere. Like sonic booms, shock waves from beneath the solar surface deposit energy in the chromosphere, heating it up. The chromosphere doesn't have a continuous rainbow spectrum like the photosphere. Only certain wavelengths — spectral lines — are bright, with hydrogen-alpha (commonly written H-alpha) the brightest. This gives the chromosphere its reddish-pinkish color.

Actually the chromosphere is not a layer. It is composed of little spikes sticking up from the surface of the sun, each one about 500 miles wide and 6000 miles high. There are a million or so of these *spicules* on the sun at any given time; they move rapidly and live only about ten minutes each.

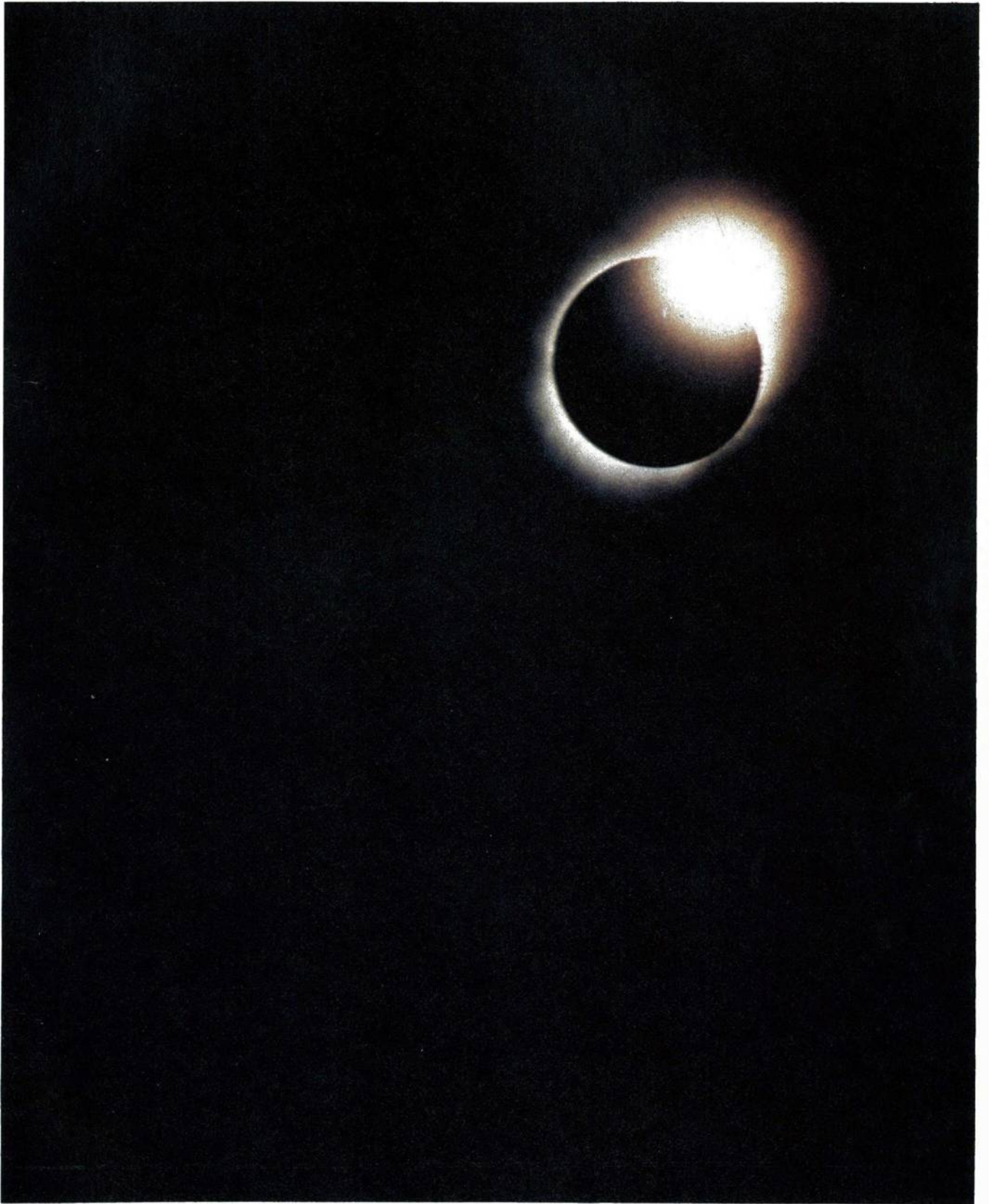
Rising above the chromosphere are the prominences. These huge arcs of glowing gas are about the same temperature as the chromosphere, but they are held high off the surface of the sun by the solar magnetic field. The lines of force of the magnetic field, like the lines of force of a bar magnet constraining iron filings on a piece of paper, hold the prominences in beautiful shapes, often loops, that can hover above the surface of the sun for days. Time lapse movies reveal that matter in these prominences is moving all the time along the sun's magnetic lines of force.

The chromosphere's outline and the spectrum of a few of its brightest lines, like H-alpha, can



During an eclipse, astronomers break down the sun's light into its component colors with a spectrograph. Here, as it emerges from totality, is a spectral photograph showing crescent shaped emission lines from the sun's chromo-

sphere. The green coronal line is faintly visible as a complete circle which corresponds to a wavelength of 5303 angstroms.



Photograph by Jay M. Pasachoff

As the moon gradually covers the sun's photosphere, a few "beads" of light, called Baily's Beads, shine through the valleys at the moon's edge. The last Baily's Bead seems

incredibly bright and as the corona brightens into view, this last bead looks like a diamond on a ring.

be studied without an eclipse. Although the chromosphere as a whole is one one-thousandth as bright as the photosphere, H-alpha itself is almost equally as bright. As a result, a special filter centered on H-alpha light is needed to show us the chromosphere and prominences. But eclipses are still necessary to study all the other chemical elements whose spectral lines are fainter.

The main point of an eclipse is to observe the corona. This pearly-white halo extends out millions of miles above the sun. We see the inner few million miles with our naked eyes at an eclipse, but the sun really expands outward in what is known as the solar wind, and even encompasses our earth in its outermost corona.

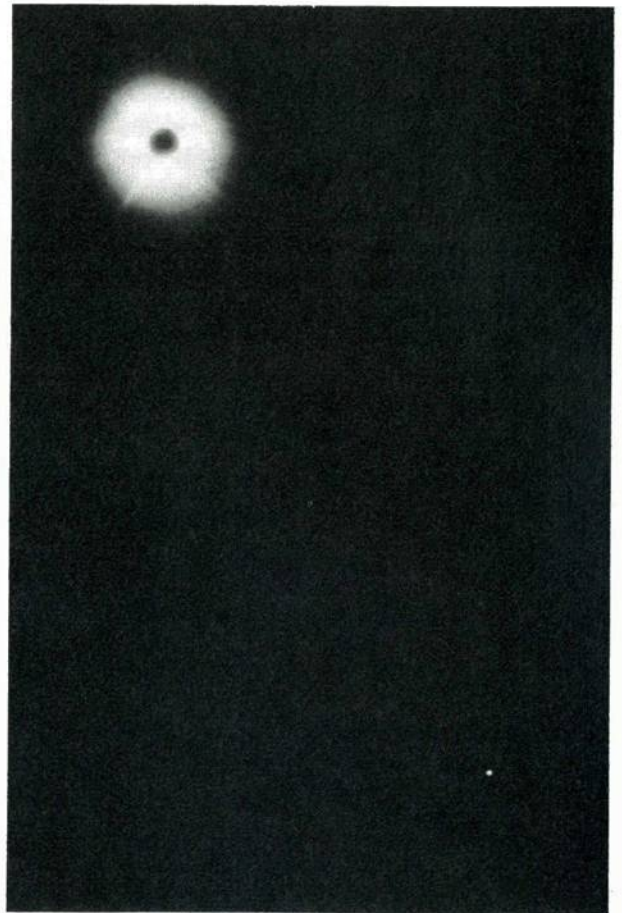
The corona is one million times fainter than the photosphere. From certain isolated mountaintops where the air is especially clear and rain-washed, using special filters under the most favorable sky conditions, astronomers are able to detect the innermost corona without a total eclipse. But these conditions are very rare and an eclipse is still needed to provide most of our information.

The corona has three separate overlapping spectra, each caused by a different effect, and separating these three is a major job that has still not been satisfactorily accomplished. First, the ions in the corona emit light directly. Their spectrum is very faint and only two dozen spectral lines are known in the entire visible range. They are important for understanding the processes operating in the corona but contribute little to the total coronal light.

Surrounding the sun, throughout the corona, are swarms of electrons stripped of atoms by the great temperature. These electrons scatter light from the photosphere. Electrons out to the side of the sun take light that is going in that sideways direction and bounce it in all directions, some of it reaching us here on earth even though the photosphere itself is blocked by the moon during an eclipse. The scattering smears out the Fraunhofer lines, leaving only a continuous faint rainbow, and the light is highly polarized.

Further out in space, perhaps around the orbit of the planet Mercury, there are dust particles that can also bounce photospheric light towards the earth. These dust particles do not smear out the Fraunhofer spectrum, nor do they polarize the light much.

To study the corona, we are really interested in the quantity of electrons, and so the dust emission must be separated from the spectrum. The spectral lines being emitted from the corona itself are just overlaid, and therefore easy to



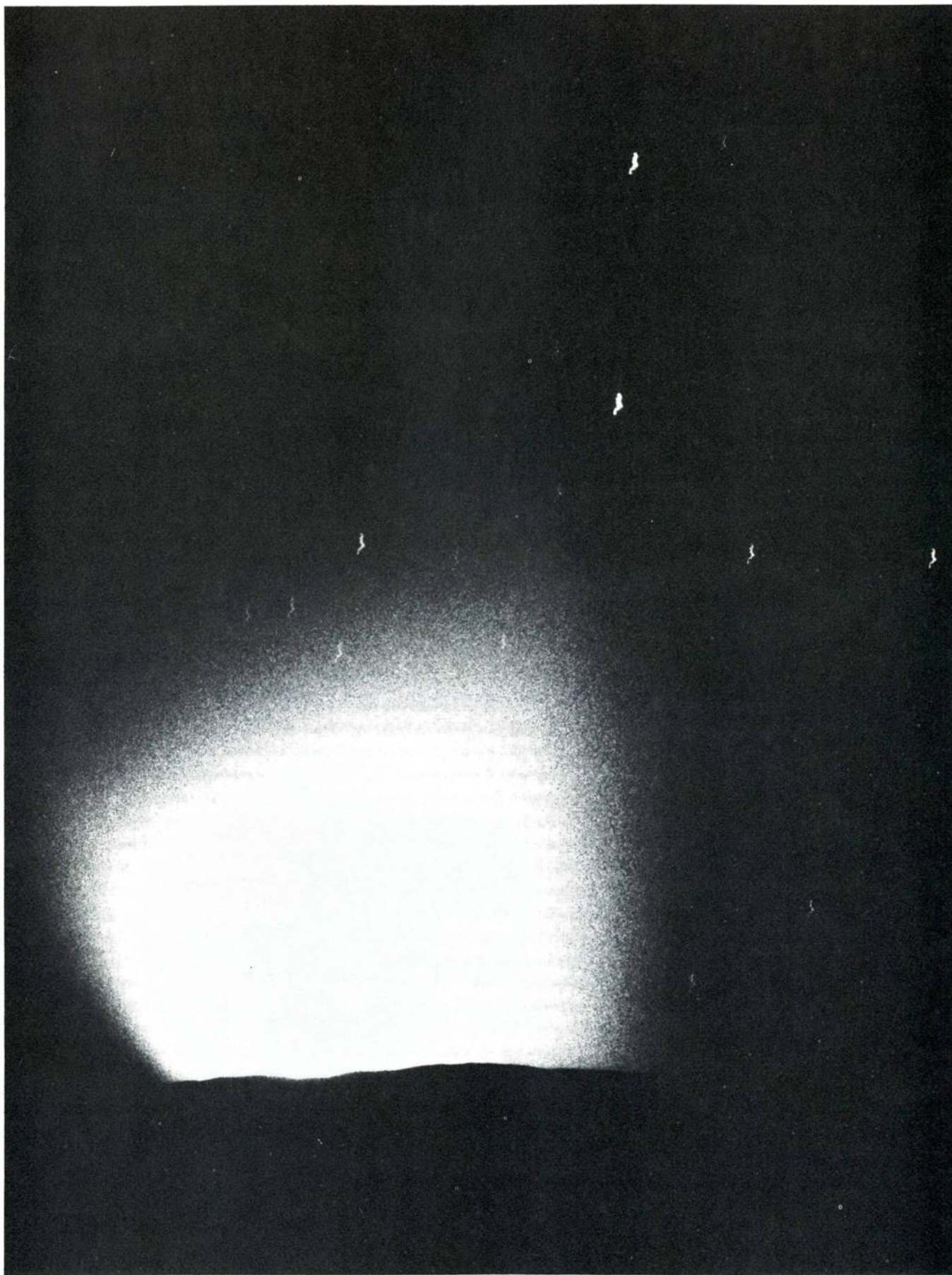
Harvard — Smithsonian — National Geographic Expedition Photograph

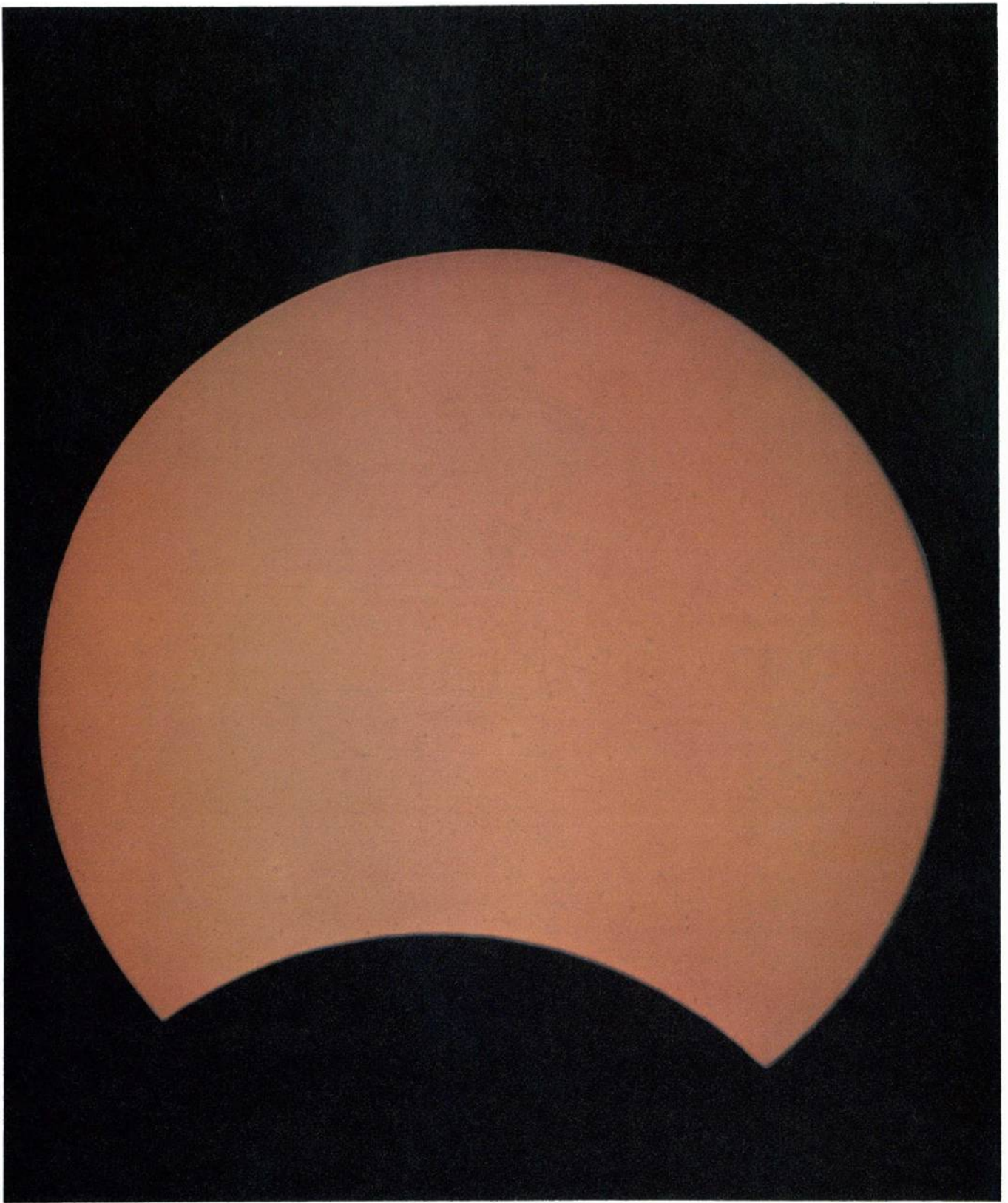
During totality at the March 7, 1970 eclipse in Mexico, the outer corona showed long streamers out to eight solar radii. This effect, normally not visible from earth, was due to unusually clear atmospheric conditions. Note that the planet Venus (star-like object at lower right) was visible during totality.

separate. But to separate the other two components, dust and ions, we must use a spectrograph to measure the polarization.

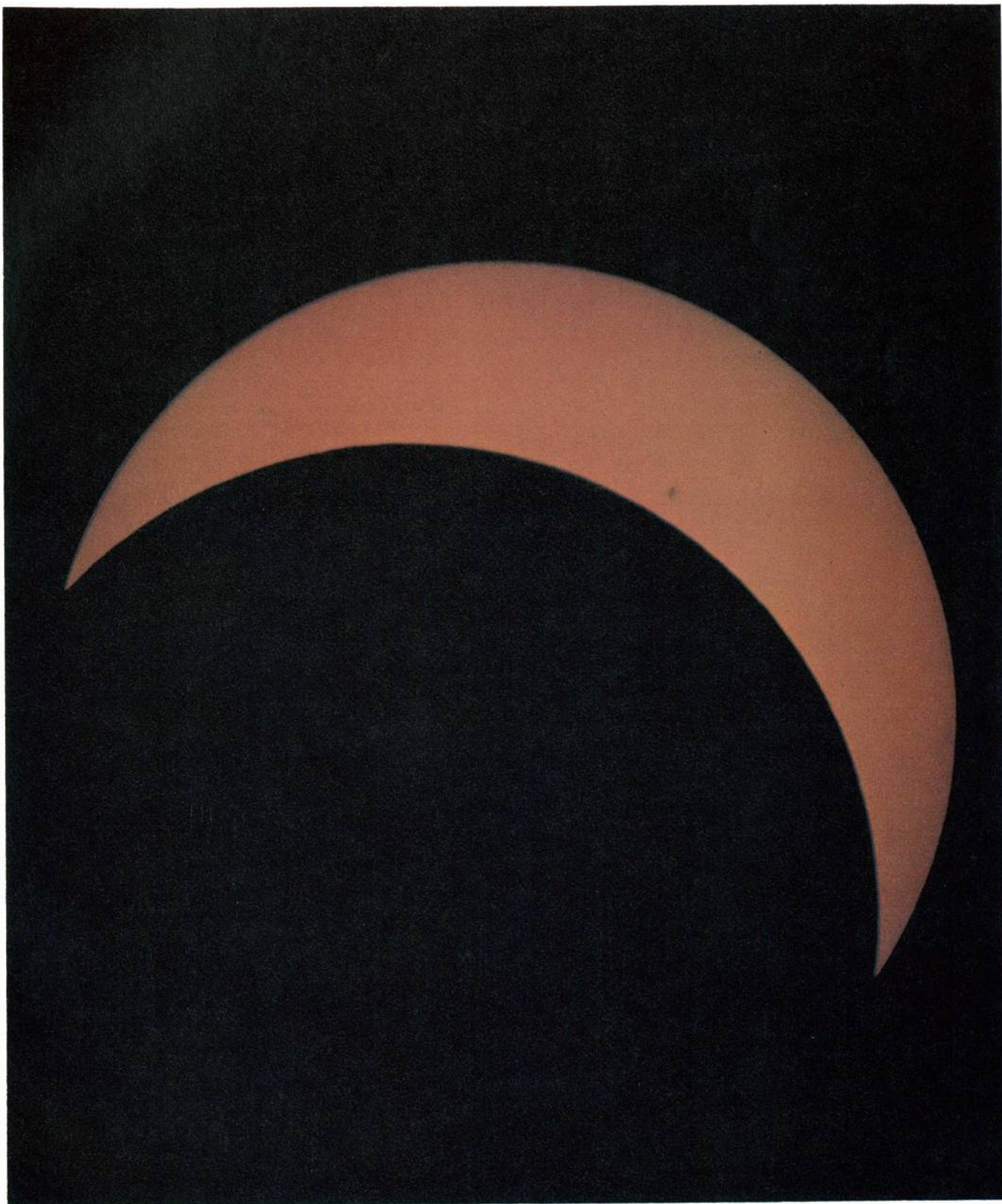
We have been able to make many conclusions thus far about the corona's composition and conditions therein, but many questions remain unanswered. One fact is quite clear: the corona has a very high temperature, four million degrees Fahrenheit on the average, with some spots hotter and others cooler. Note that this high temperature merely means that the individual ions

The sun's corona (right), photographed from Apollo 15 one minute before a spacecraft sunrise on July 31, 1971, is seen just above the dark horizontal edge of the lunar horizon. The bright object near the top is the planet Mercury and the bright star near the center is Regulus, the brightest star in the constellation Leo. A careful study of coronal brightness allows a better scientific interpretation of the energy transfer from the sun outward into our solar system.





As it revolves about the earth during an eclipse, the moon gradually blots away more and more of the sun's disk. For the unfortunate majority of eclipse viewers living on either side of the path of totality, only a portion of the sun



Photographs by Rob Duisberg

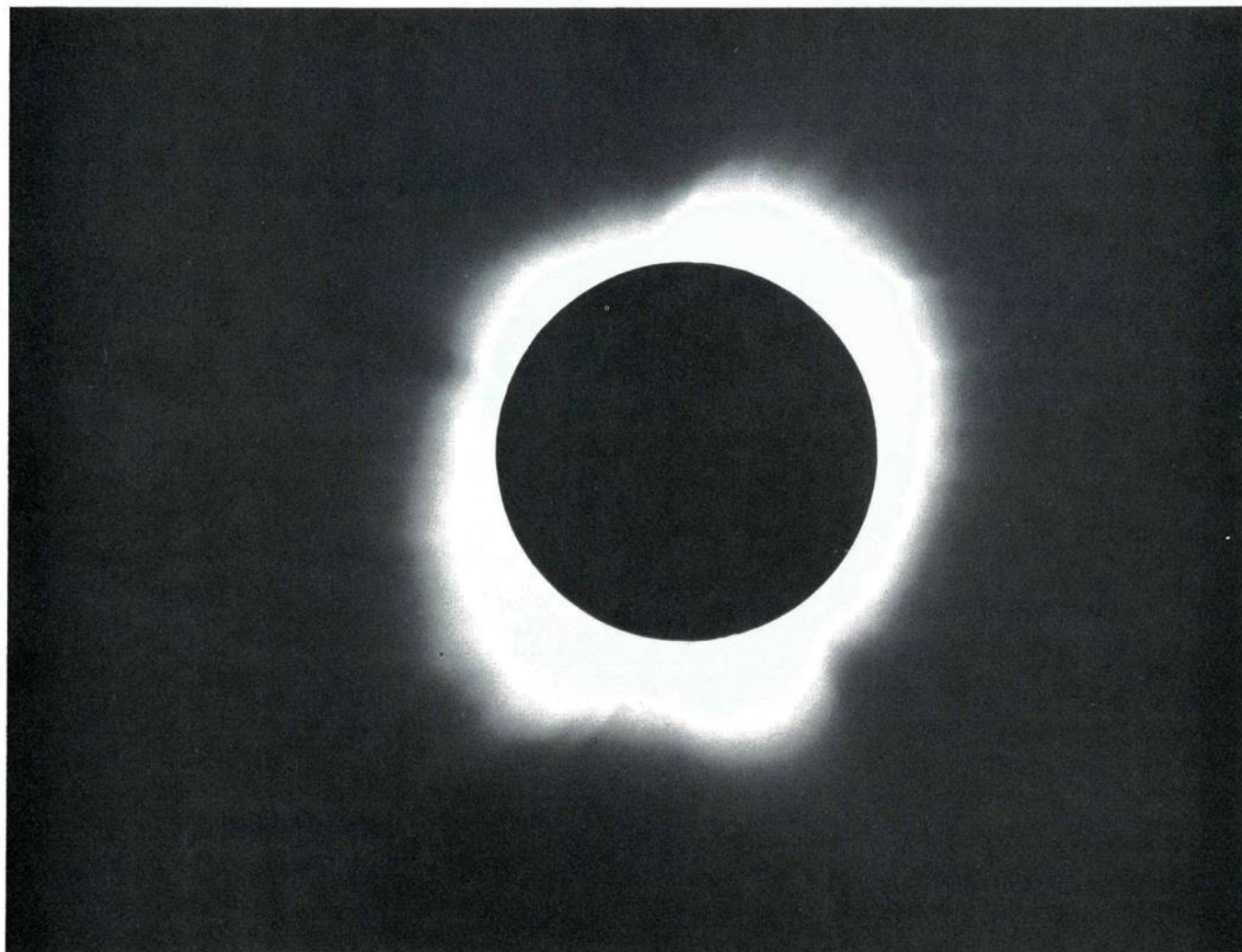
is blotted out at maximum coverage. During maximum coverage, an observer located far from the path of eclipse totality might see the sun as it appears at left, while someone closer to totality might see it as above.

in the corona are moving around very quickly, and temperature is defined in terms of the average velocities of the particles. The amount of energy in the corona is not large because its density is very low.

Actually the corona is a very good vacuum, in fact as good as any that we can make in laboratories on the earth. Under the conditions of the corona, with the high temperature and low density, electrons are ripped off atoms. In the chromosphere, one or two electrons might be torn away from an atom, but conditions in the corona are much more extreme. We find iron, for example, that has lost 13 of its 26 electrons. Nowhere on earth can we experiment for any length of time under such extreme conditions. In effect the sun is our closest laboratory for the study of high energy physics.

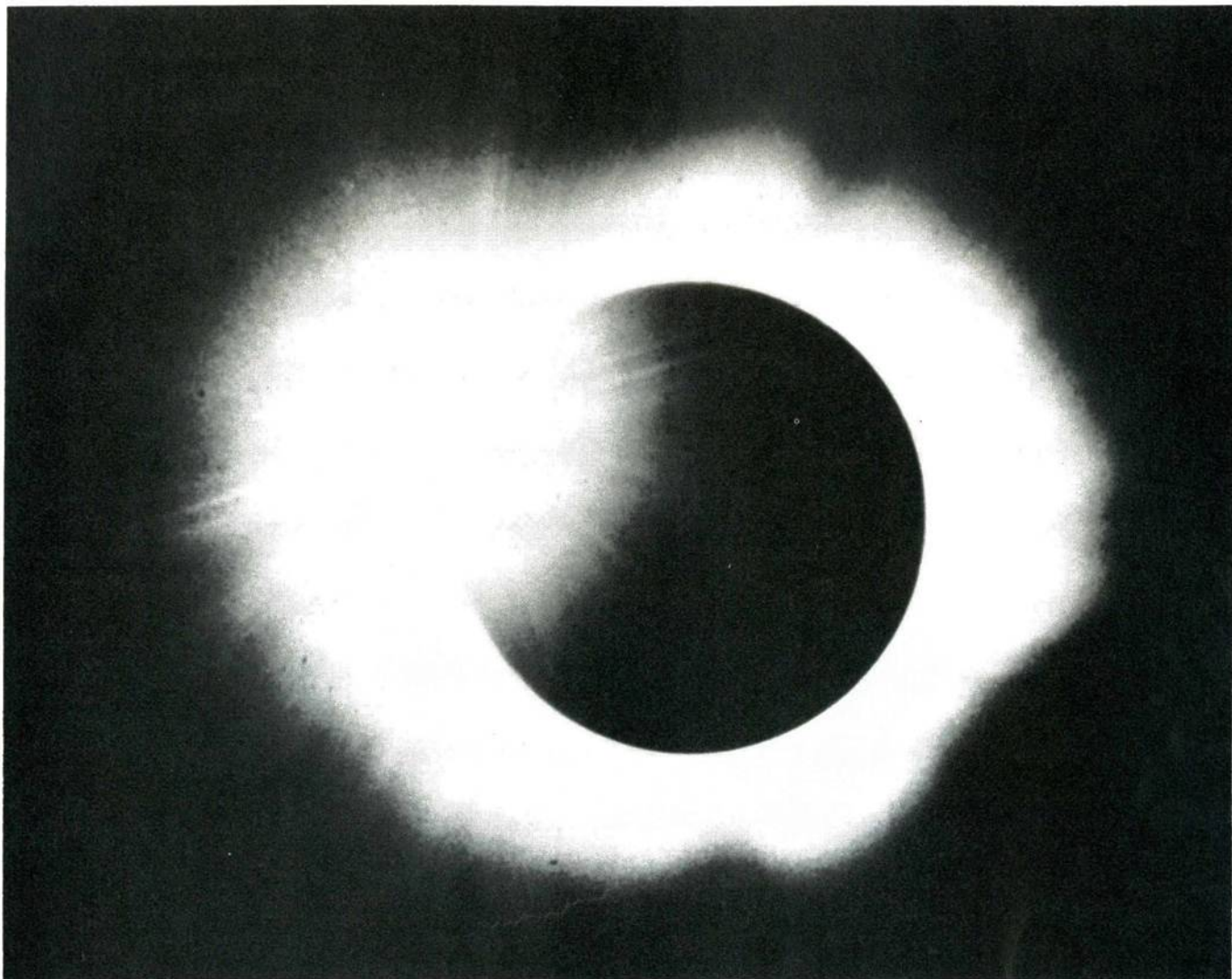
At an eclipse we can study the spectrum of the solar corona, and measure its polarization. We are able to see its beautiful shape, which traces out the sun's magnetic fields. Near the poles of the sun's rotation are little tufts of corona. On occasion near the equator are long coronal streamers that often extend 10 million miles or more into space, dwarfing the earth. Intermixed are regions of less emission where the density might be much lower. These are the newly discovered "coronal holes", now the subject of much research.

In recent years, the corona has been studied from space. A series of satellites called Orbiting Solar Observatories were launched by NASA. They observe the ultraviolet part of the spectrum where the coronal ions emit most strongly. Thus, they are able to observe these ions across the entire surface of the sun without an eclipse. At



Harvard — Smithsonian — National Geographic Expedition Photograph

The solar corona viewed at totality from Miahuatlan, Oaxaca, Mexico during the March 7, 1970 total solar eclipse.



Harvard — Smithsonian — National Geographic Expedition Photograph

The diamond ring effect, also photographed in Mexico during the 1970 eclipse.

these ultraviolet wavelengths it is the corona and not the photosphere that is brightest. Results from satellite observations have been tied in with eclipse results to create better models of the corona.

The latest satellite in the series, OSO-7, is equipped with a "white-light" coronagraph, a telescope that takes advantage of the dark skies above most of the earth's atmosphere to observe the corona. Conveniently it blocks out the photosphere and the inner corona occulting everything within three times the solar radius. As a result we receive daily pictures from OSO-7 of the outermost corona, beyond the part that can be studied from the earth, even beyond the part ordinarily studied during an eclipse. This information, however, does not overlap with the inner section

studied carefully at eclipses. Further, the resolution of the television system that sends back data from OSO-7 is far inferior to the resolution available on film from earth-based eclipse observing sites.

The Skylab space station has on board photographic coronagraphs that should provide improved resolution. However, it generally appears that for some time satellite and earth-based eclipse observation will be complementary, rather than competitive.

In the mysterious depths of the universe, few splendors rival the beauty of a total solar eclipse. Although man's technological journey to the stars may, in time, diminish the scientific value of studying an eclipse, this splendid event will remain immortal as one of Earth's most valued, natural treasures.



Mercury



Venus



Earth



Mars



Jupiter



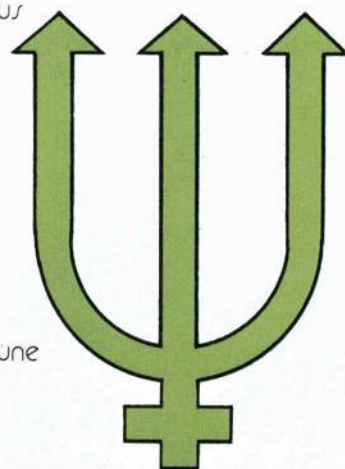
Saturn



Uranus



Neptune



Pluto



Planet X



IN SEARCH OF PLANET X

by

Wm. Bruce Weaver, Ph.D.
Monterey Institute for Research in Astronomy

Considerable interest and controversy has been raised in astronomical circles recently over the prediction of a new, major planet in our solar system.

Historically, ancient astronomers were familiar with the brightest planets - Mercury, Venus, Mars, Jupiter and Saturn - simply because they were bright enough to be seen without a telescope. It was only by accident that Sir William Herschel telescopically discovered Uranus March 13, 1781 while routinely surveying the stars in the constellation Gemini. After Uranus, other methods were needed to discover additional planets in our solar system, if more existed.

The eighth planet from the sun, Neptune, was the first to be discovered using modern predictive methods. If no other planets existed beyond the orbit of Uranus, this seventh planet should have followed the path calculated by astronomers. Since Uranus did not adhere to its calculated orbit, it was reasoned that a "Planet X" must exist beyond the orbit of Uranus, and have enough gravitational influence to cause irregularities in Uranus' orbit.

Studying the irregularities in Uranus' orbital motion, John C. Adams, a young Englishman, was

able to predict the position of Planet X. A Frenchman, Leverrier, also determined Neptune's position mathematically. September 23, 1846, the first Planet X, Neptune, was observed at Berlin Observatory less than one degree away from its expected position.

When Neptune's gravitational pull on Uranus was taken into account, the errors in Uranus' orbit were reduced to 1/60 of what they had been. However, the remaining discrepancies were large enough to launch Percival Lowell on his famous search for a new Planet X in 1906. Although Lowell died in 1916, the search he instigated went on until February, 1930, when Clyde Tombaugh discovered the new planet photographically. Since its discovery some astronomers have argued that Pluto is not massive enough to cause the orbital irregularities of Uranus that were used by Lowell. Because of this, the discovery of Pluto may well be the most fantastic coincidence in the history of science.

Not all Planet X's were real. Mercury is the smallest planet in the solar system and the closest to the sun. Its orbit is slowly changing in a way which can't be explained by classical Newtonian gravitational theory, and some astronomers

believed that a planet closer to the sun than Mercury might exist. So sure were they, that they prematurely named the hypothetical planet *Vulcan*. While this elusive planet was supposed to cause the slow change in Mercury's orbit, Vulcan was never found. Much later the strange motions of Mercury's orbit were explained by Einstein's general theory of relativity.

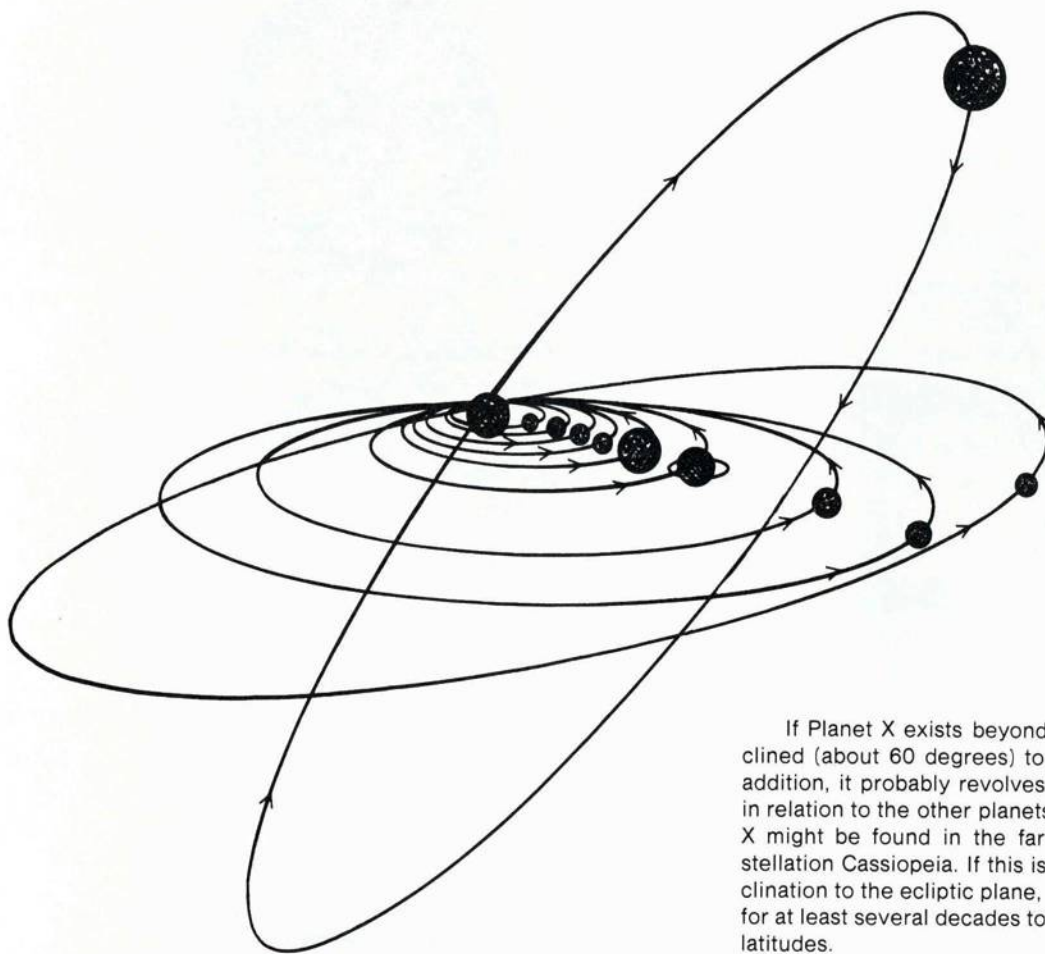
Using a computer recently to study disturbances in the motion of Halley's Comet since 295 A.D., Joseph Brady of the University of California Lawrence Livermore Laboratory, predicted that another Planet X should exist beyond the orbit of Pluto. This hypothetical planet would be twice as far from the sun as Neptune and have three times the mass of Saturn or nearly 300 times the mass of Earth - in fact, it would be more massive than all the other planets except Jupiter.

Brady employed the same method used to find Neptune and Pluto. However, instead of looking for irregularities in the orbit of Uranus, he looked for these irregularities in the orbit of

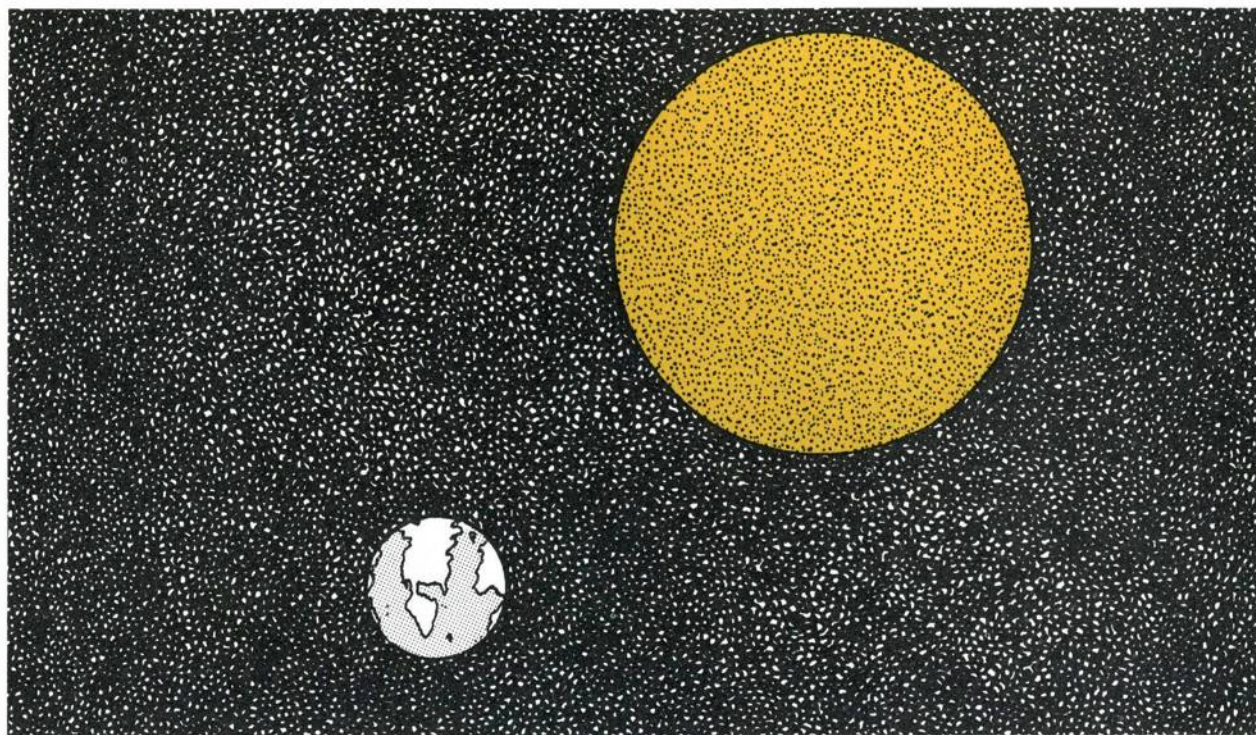
Halley's Comet. (This comet regularly returns every 76 years and has been observed since at least 87 B.C.) By carefully choosing just the right mass, position and motion for his new Planet X, Brady found he could reduce the difference between the comet's calculated and observed orbits by 93%.

If this new Planet X exists, it will be the strangest planet in the solar system. For example, all the known planets travel in orbits confined to the same approximate plane, called the plane of the ecliptic. In other words, if we represented the sun and the planets on a flat tabletop, none would be very far above or below the table's surface. Pluto is the only oddball exception - its orbit is inclined a whopping 17 degrees from the plane of the ecliptic. Planet X would have an even greater inclination (60 degrees) which would place it far north of the ecliptic at this time.

Moving outward from the sun the planets become larger and larger until Jupiter, the largest. Then they start getting smaller again. Planet X, far beyond Pluto, would probably be the second



If Planet X exists beyond Pluto, its orbit is steeply inclined (about 60 degrees) to the plane of the ecliptic. In addition, it probably revolves around the sun "backwards" in relation to the other planets. Astronomers believe Planet X might be found in the far northern sky near the constellation Cassiopeia. If this is true, because of its large inclination to the ecliptic plane, Planet X would not be visible for at least several decades to observers in higher southern latitudes.



Joseph Brady of the University of California Lawrence Livermore Laboratory has predicted that a Planet X, twice as far from the sun as Neptune and 300 times more massive

than the earth, should account for discrepancies in the motion of Halley's Comet since 295 A.D.

largest planet in the solar system, which does not fit the apparent pattern. In addition, all the planets are moving around the sun in the same direction. Most astronomers believe this tells us something about the way the solar system was formed, especially since the sun rotates in the same direction. But Planet X would be moving around the sun in the opposite direction. It would be difficult to fit this retrograde motion into current theories on the formation of the solar system.

The critics of Brady's Planet X point out that a planet as massive as he suggested, and positioned so far above the ecliptic plane, would strongly disrupt the orbits of the outer planets. The gravitational attraction from this giant Planet X would pull the planets Jupiter, Saturn, Uranus, Neptune and Pluto out of their present orbits. Since the planets are not being pulled out of their ordinary orbits and in view of what is known about the physics of the solar system, critics point out that such a planet is highly unlikely.

Still, the possibility of discovering a new planet is very exciting to most astronomers. Because of this, photographic searches have been made covering a substantial area around its predicted position, but nothing has been found. It took 24 years to find Pluto, and astronomers are not yet willing to completely rule out the exist-

tence of Planet X. However, the observational evidence against Planet X seems fairly strong.

If Planet X doesn't exist, astronomers ask, what makes Halley's Comet act so strangely? Comets can best be described as dirty icebergs. The molecules in the ice are probably methane, ammonia and water. As the comet approaches the sun, the ice starts to sublimate (change directly from an icy state to a gaseous state), and molecules and parts of molecules fly off into space. Excited by the sun's radiation, this gas glows and forms the familiar tail, which may be as long as 100 million miles. Sometimes this sublimation may occur quite rapidly from only parts of the comet, acting like a weak jet and changing the comet's orbit slightly (an effect observed in some shorter period comets). Brady's critics point out that if you "scale-up" non-gravitational effects observed in the lesser comets, you would have about the right effect on the orbit of Halley's Comet.

It seems now that most of the evidence is against the existence of a new Planet X. All the arguments of the critics will crumble to dust, of course, if someone finds it. If it isn't found, it probably means that there are no undiscovered major planets in the solar system.



MYSTERY STARS

by
R. Newton Mayall

GAZER'S GAZETTE

Does your telescope collect dust because you are tired of looking at the sun, moon and planets? If so, why not try observing those mysterious stars called "variables".

Unlike other stars whose magnitude or brightness is stable, these mystery stars vary in light intensity. Many have peaks (maxima) and lows (minima) that occur at regular intervals, but others vary in many different ways and there is no way of telling what they will do. Because they are so mysterious they can be fascinating to the observer.

The time between one maximum and another, or between one minimum and another is called the period of variation. Some variables have a definite rate of periodicity, while others are quite irregular. Many long period variables take hundreds of days and even years between maxima and minima while others with short periods take as little as a day or a few hours.

The variation in magnitude is from the smallest measurable difference to as much as eight or ten magnitudes or more. A typical example is Algol (Beta Persei) which varies only about 1-1/4 magnitudes in a period of about three days, with great regularity. Another is exemplified by the star Omicron Ceti, or Mira the Wonderful, which ranges from a very bright 2nd magnitude star to a faint 10th magnitude star. Mira remains bright for about 10 days; then its light wanes for about eight months after which it rises to maximum, sometimes very rapidly. With optical aid it can be observed throughout its range.

Variables may be put into two types: *intrinsic*, where the variation is caused by physical change within the star itself or in its surrounding atmosphere, and *extrinsic* where the variation is due to an eclipsing effect in a star system containing two or more bodies (binaries). Intrinsic stars include irregular, rapidly changing stars, pulsating stars, red variables, and explosive stars. Some have regular periods, some semi-regular, while others are irregular. Still others cannot be included in any class.

Pulsating Variables

Pulsating stars vary in brightness because they are continually contracting and expanding, becoming alternately hotter and cooler. Typical of these are the "classical Cepheids", which show a definite correlation between period and luminosity (brightness). By comparing their true brightness (magnitude at a specified distance from the sun) with the apparent magnitude (brightness as seen from earth), the Cepheids' distance from the earth may be easily calculated. These stars are also found in other galaxies and therefore have become yardsticks for our universe. Cepheids vary from 0.1 to 2 magnitudes with periods ranging from one to 50-75 days. The term Cepheid is derived from the variable Delta Cephei which is typical of this class of variables.

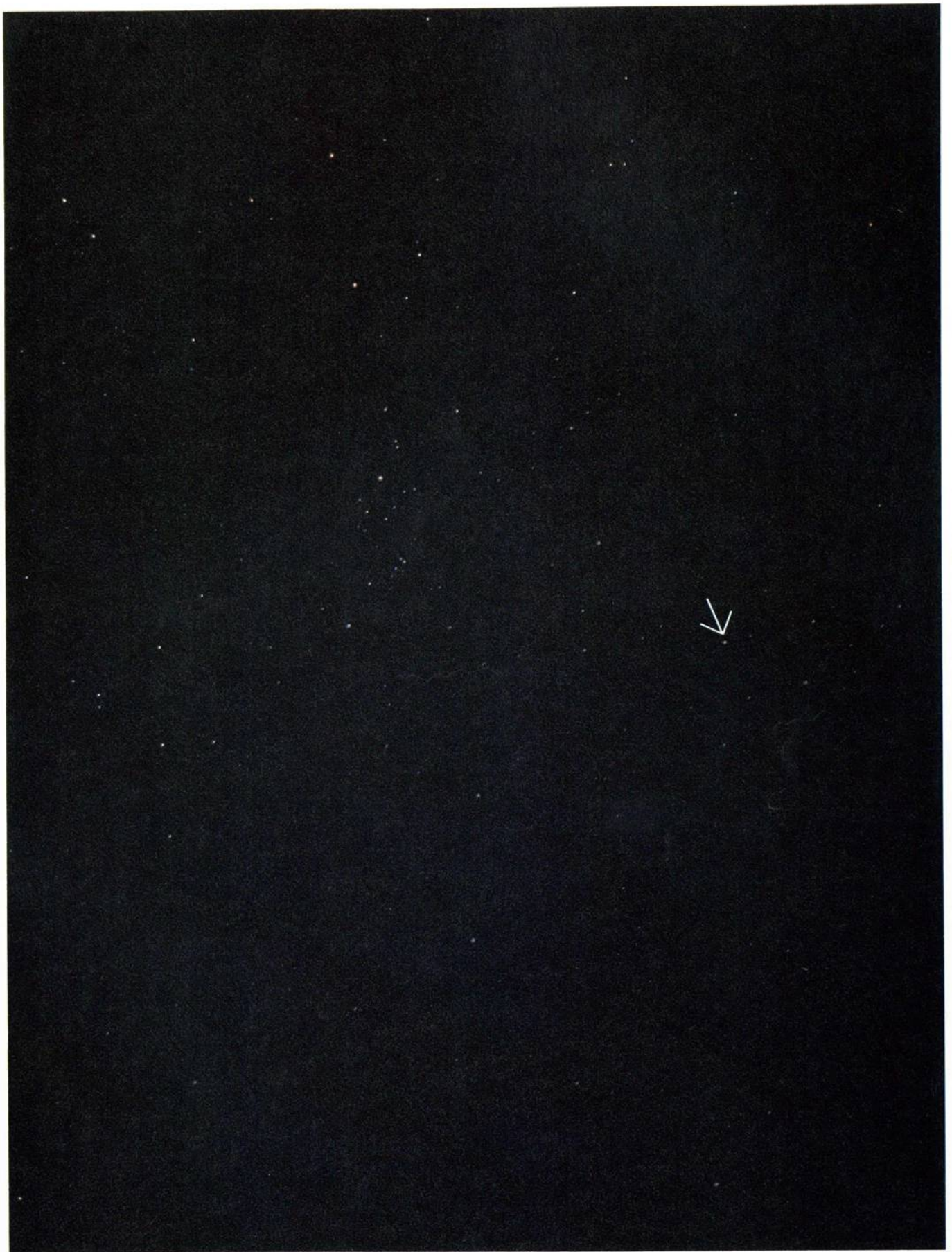
Red Variables

Red variables, whose periods have been determined, have much longer periods and larger ranges of brightness than the Cepheids. Typical of this group is Mira.

Explosive Stars

Explosive stars are the novae, or new stars, which have sudden outbursts of brightness of eight or ten magnitudes, then a long slow return to their original magnitudes. Then there are the so-called supernovae where the brightness may increase as much as 20 magnitudes. However, there have been only a few supernovae in our galaxy. Some novae have two or more maxima some years apart. These are called recurrent novae. A few variables, such as SS Cygni, have a variation of nova-like character, but their maxima occur at irregular intervals, and their mean cycle remains fairly constant over the years. Their outbursts are less violent than those of novae and may vary from two to six magnitudes.

An outstanding example of eclipsing variable stars is found in the constellation Perseus (see Star Dome). Algol, indicated by an arrow above, has a stable magnitude of 2.3 for about 2 1/2 days. For 2.9 days, the star dims to magnitude 3.5 and then back to 2.3 as a dim companion star blocks out part of Algol's light.



Eclipsing Variables

Binary stars are those consisting of two bodies close enough so that they orbit each other around a common center of gravity. Two stars that appear close together as we see them from earth, but have no physical connection, one being farther away from us than the other, are called optical doubles. Stars that are observed to be one star moving about another are called visual doubles, and they move about their common centers of gravity. If their orbits are in our line of sight they are called eclipsing binaries. Algol (Beta Persei) is typical of an eclipsing binary. Its variation is due to a dark body passing in front of Algol at regular intervals. More than four thousand eclipsing binary stars are known.

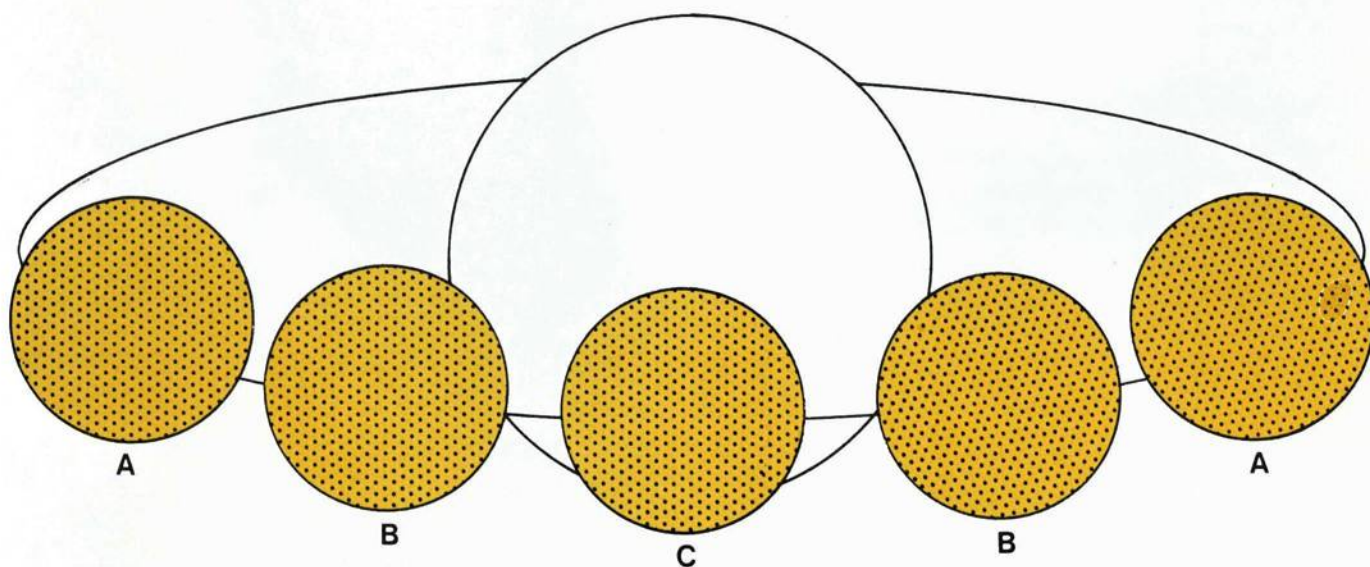
On any star atlas variables are marked without any regard for whether they are intrinsic, extrinsic, pulsating, explosive or eclipsing binary. They are simply noted by a single capital letter, double capital letters, or by a V followed by a number, except where a variable previously has been designated by a Greek letter.

In general, the first variable discovered in a constellation was given the letter R, the second S and so on until Z was assigned. Then it was decided to repeat the letters with RR, RS to RZ; SS, ST to SZ etc. to ZZ; then AA, AB, etc. Some con-

stellations have so many variables it became necessary to allot numbers. The 334th variable in a constellation was labeled QZ, and the next one was assigned V335. In Sagittarius alone, over 2,500 variables are known.

Although we know certain stars vary in brightness, we still do not know the cause. For that reason amateurs throughout the world watch these mysterious stars. Why? For the sheer joy of doing something useful and contributing to our knowledge of the universe. They don't just look at a variable; they study it to see how bright it is in relation to other nearby stars whose brightness does not change.

The American Association of Variable Star Observers (AAVSO) provides charts which show each variable under observation and its comparison magnitude stars. Members throughout the world keep under constant observation more than a thousand variables of all types. They do this by comparing the variable with the comparison stars and estimate the variable's brightness. A comparison star that is brighter and one that is fainter than the variable make it possible to estimate to tenths of a magnitude. At the end of every month members send their estimates of the stars observed to the headquarters of AAVSO where they are plotted, analyzed, compiled and



An eclipsing variable star is actually two stars revolving about each other. In this illustration the large star is brighter. When the small dim star is at position "A" in its orbit around the large star, it looks brighter in the night sky. As the small star gradually moves to positions "B" and "C", it blocks out

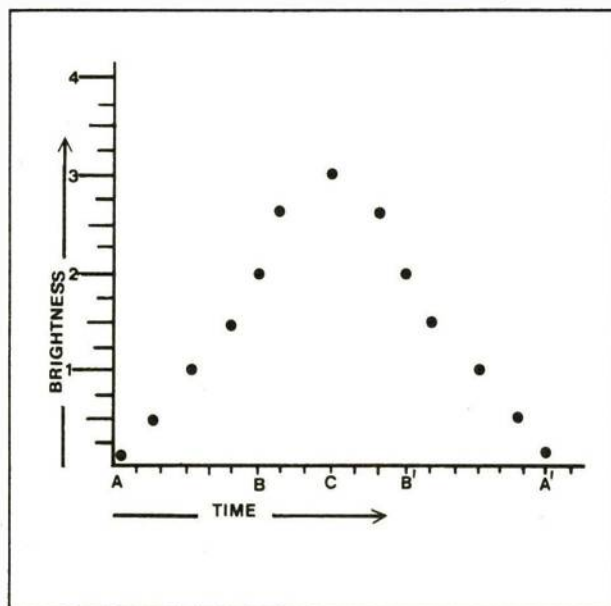
some of the bright star's light, causing the star system to grow dimmer in the sky. The eclipsing binary star system then grows brighter again as the dim star moves to positions "B" and "A" in its orbit. This dimming/brightening effect is plotted in a light curve on page 23.

made available to professional astronomers. The end result of the observations is a "light curve" which is obtained by plotting magnitude against a time scale. (See illustration.)

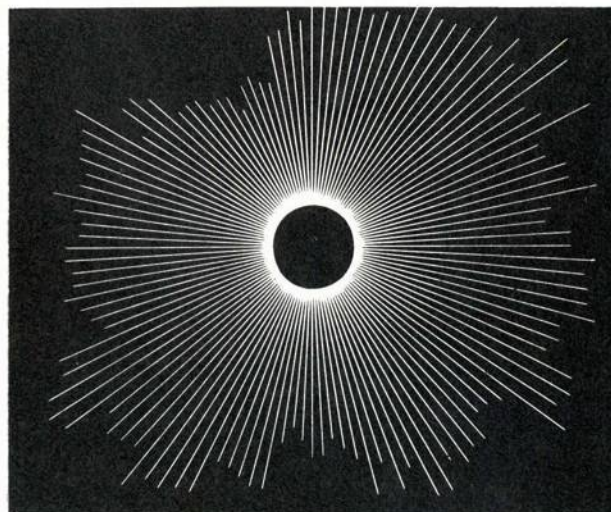
When the brightness of a variable has been estimated it is recorded on a special report form, which includes the date, the designation, name of the variable, and its magnitude, together with the size and location of the telescope, and time of observation. The observer keeps careful records and, because he may observe from dusk to dawn, he uses a different calendar — the Julian Day Calendar. This calendar counts the days from noon to noon thereby making the use of two dates unnecessary. It is the number of days which have elapsed since 1 January 4713 B.C. For example, Julian Day 2,441,684.0 = 1.5 January 1973 Universal Time (UT).

Universal Time is the same as Greenwich (England) Mean Time. The observer transposes the standard time of his locality to Universal Time. For example: an observation made at 9:00 p.m. EST on July 10, 1972 becomes 14:00 hours UT, by adding five hours. This becomes Julian Day 2,441,509.6 as determined from Julian Day Calendars and decimals of a day, which are provided by the AAVSO.

Each variable is given an identification



Hundreds of magnitude estimates result in an average magnitude plot at given time periods for any variable star. These averages are then converted to single magnitudes which, when plotted on a graph, form a curve as in the above illustration. Discrepancies in this light curve over many years tell astronomers about conditions in stars that are intrinsically variable.



Pulsating variables continually expand and contract. This activity accounts for their increases and decreases in brightness. Since their rhythm is regular, pulsating variable stars, such as the Cepheids, are used by astronomers to measure distances to stars in our galaxy and to other galaxies.

number which is referred to as the Harvard Designation, the approximate position (right ascension and declination) of the star in 1900. For example: Algol's designation is 030140. The first four figures represent the hours (03) and minutes (01) of right ascension and the last two refer to its declination (40 degrees). If south declination, the last two figures are underscored.

What becomes of the observations after they are made? Why are the observations necessary? The observations are plotted and kept up to date, and are available to professional astronomers to show what any specific variable is or was doing at any particular time. All observations are put on punch cards, which are run through a computer that produces an average light curve.

The professional astronomer uses vastly different techniques in observing variables — the spectroscope and other delicate methods that are too expensive for the amateur.

The amateur can do much that the professional cannot. With over 125,000 observations a year coming in from all over the world, the amateur is in a unique position, for he provides the professional with much needed data which he cannot obtain easily himself.

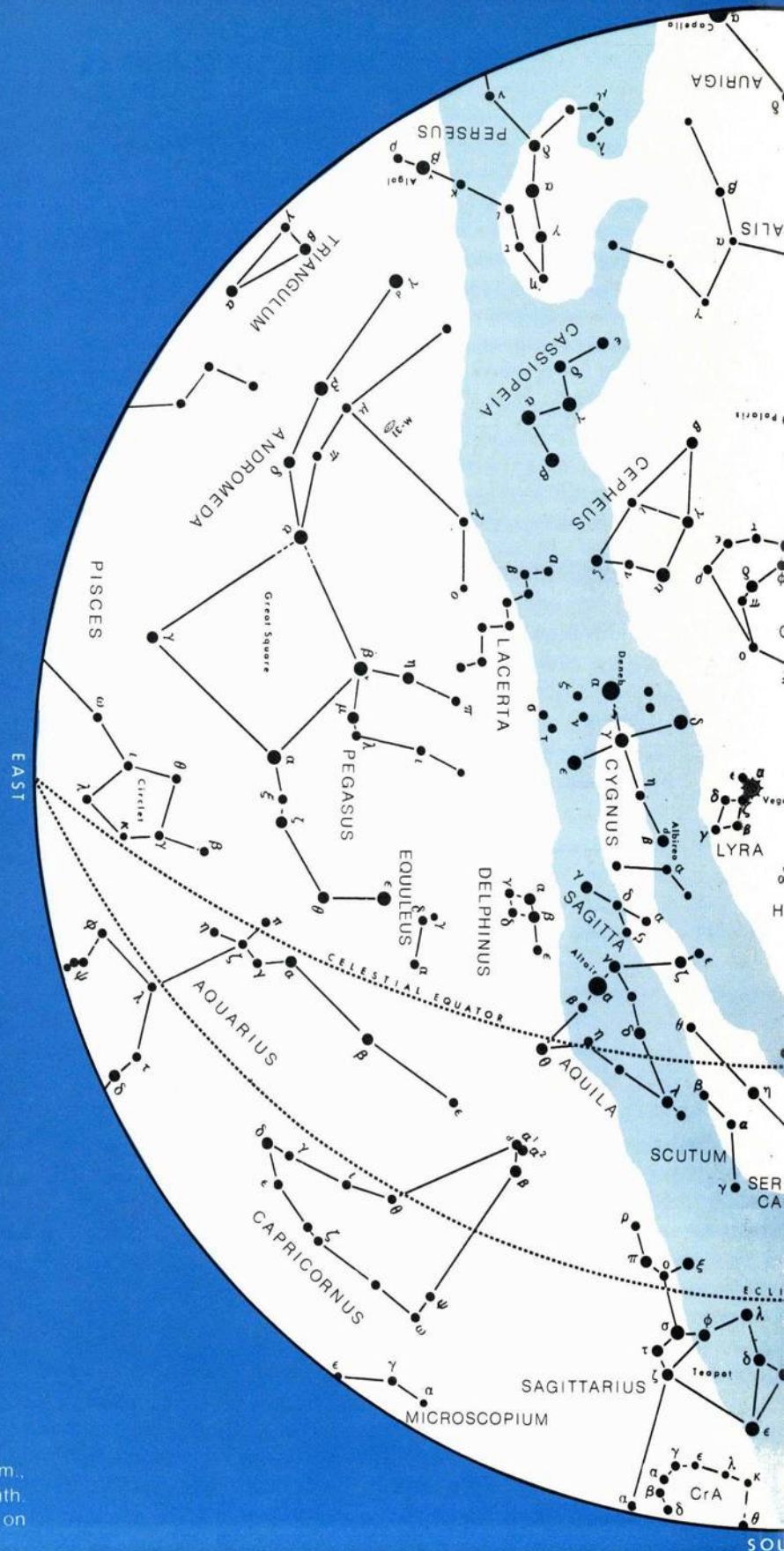
If these mystery stars intrigue you, why don't you turn your telescope on them? If you do not want to join any organized program of observing, you might like to try plotting a light curve from your observations and make your own estimate of the period.

Magnitudes

- ☉ Zero
- First
- Second
- Third
- Fourth
- Fifth

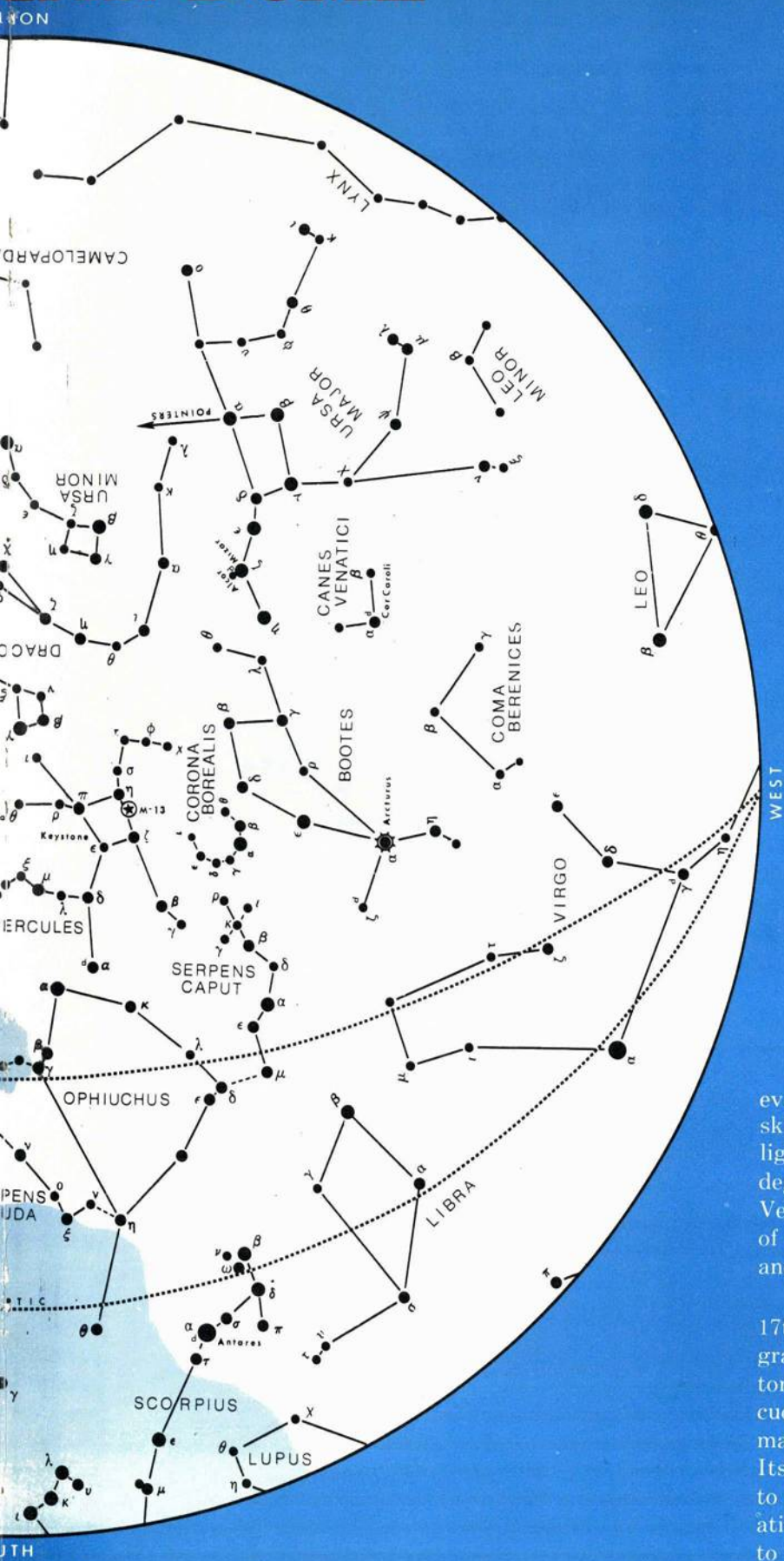
Objects

- ★ Open Clusters
- ⊙ Globular Clust
- Diffuse Nebula
- ☄ Galaxies
- Double Stars
- Variable Stars



Star Dome approximates the sky as it appears at 10 p.m., Local Daylight Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th.

TAR DOME



by

John G. Harmon
Manfred Olson Planetarium
University of Wisconsin — Milwaukee

Almost directly overhead on a clear August evening shines the brightest star in the summer skies. This is Alpha Lyrae or Vega, the "arc-light of the skies". Vega lies within about ten degrees of being circumpolar. This means that Vega is above the horizon for about 18 hours out of every 24, and can be seen at sometime or another on any clear night.

Vega has several claims to fame. On July 17th, 1850 it became the first star to be photographed. This was done at the Harvard Observatory by the Daguerrotype process. This conspicuous blue-white star is also one of the stars that marked the North Celestial Pole in ancient times. Its last reign as our north star was from 12,000 to 11,000 B.C. and like Thuban in the constellation Draco, some Egyptian temples were aligned to it. As the proper motion of our sun brings us

closer to Vega over the coming centuries (at the rate of 12 miles per second), its brightness will gradually increase.

Vega is the brightest star in the constellation of Lyra, the lyre or harp. In Greek myths, it is the harp that was invented by Hermes by stretching strings across an empty tortoise shell. To atone for one of his many pranks, Hermes gave the harp to Apollo, who was the god of music. Apollo lent this harp to Orpheus, the musician. With this lyre, Orpheus was able to make music that charmed not only men, but birds, trees, rocks, and the sea as well. Apollo was pleased by all this until Orpheus fell in love with Eurydice. Orpheus then began to neglect his music, and in anger Apollo sent a serpent to sting Eurydice to death. The grieving Orpheus went to Hades to search for her, accompanied by the music of his harp. This music charmed Pluto, the king of Hades, who permitted Eurydice to follow Orpheus back to the world of the living. However, Orpheus was not to look back at her until after they had left Hades. As they neared the surface, curiosity overcame him and he glanced back, only to have Eurydice fade from his view. Orpheus lived a lonely, unhappy life and upon his death, Apollo took back his harp and placed it among the stars.

A number of other cultures saw Lyra as a harp with some similarities in their attendant legends. One notable exception was the ancient Arabs, who saw Lyra as the Swooping or Falling Eagle from which the name Vega is derived.

Vega is also part of a group of three bright stars called the Summer Triangle. The other stars in the group are Deneb (Alpha Cygni) and Altair (Alpha Aquilae).

Deneb, the brightest star in the constellation Cygnus, the Swan, is also one of the intrinsically brightest stars in our skies. It is a blue supergiant with an absolute visual magnitude of -7.1. This makes Deneb about 60,000 times brighter than our sun. At a distance of 1600 light years this blue supergiant dims to a star of first magnitude in our skies.

There are three major legends concerning Cygnus. The first claims that it represents Orpheus, who was transformed into a swan and placed in the sky near his harp, Lyra. The second legend is that Cygnus is the swan into which Jupiter changed himself when he visited Leda, the wife of the king of Sparta, and the mother of Castor and Pollux. The most popular legend though, is that of Cynus who was a close friend of Phaethon, the son of Apollo.

Phaethon was permitted by his father to drive

the chariot of the sun for one day. Unfortunately, Phaethon could not control the horses and the chariot approached too close to the Earth. It was just about to burn up when Jupiter struck Phaethon with a thunderbolt. He was hurled into the River Eridanus and disappeared beneath its waters. Cynus dove into the river and searched for Phaethon's charred remains so he could bury them. He swam about for a long time with his head occasionally beneath the surface. The gods finally took pity on him and turned him into a swan which they placed in the sky. When you see a swan today, swimming with its head beneath the water, it is supposedly still looking for the body of Phaethon.

The constellation of Cygnus is also referred to as the Northern Cross. This is a descriptive name for the cross-shaped asterism which becomes most apparent at Christmas time when it stands upright on the northwestern horizon at sunset.

The third constellation in the Summer Triangle is Aquila the Eagle. Aquila's brightest star is Altair, which takes its name from the Arabic name for the constellation, Al Nasr al Tair. Aquila is associated with the god Jupiter who sent an eagle to earth to bring back Gany-mede to serve as the cup bearer for the gods.

In this context, Aquila is often associated with nearby Aquarius who, according to some sources, represents Ganymede. The constellation is also said to represent the eagle which preyed upon the liver of Prometheus.

The constellations of the Summer Triangle are often mentioned together in legends of other lands. In this vein, they are sometimes pictured as a swan with two eagles in flight; Lyra being known as the "Falling Eagle", and Aquila the "Flying Eagle".

One last but very different legend comes to us from the Chinese, and ties together the constellations to Aquila and Lyra. It is the story of "The Spinning Damsel and the Magpie Bridge". A cowherd, represented by Alpha, Beta, and Gamma Aquilae, fell in love with the Spinning Damsel, the stars we see as Lyra. The Damsel's angry father banished them to the sky where they could meet only once a year and then only if they could cross a river marked by the Milky Way. In order for them to meet, every year on the seventh night of the seventh moon, their friends the Magpies meet to form a bridge over which they can cross the river. Essentially similar legends concerning these stars can also be found in both Korea and Japan.



Optics for Astrophotography

by
John Sanford

One of the most important considerations in photography of celestial objects is optics. This includes lenses, mirrors, and lens/mirror combinations called catadioptrics.

Since optics play such an important role, following are four basic principles of optics as they apply to astrophotography:

1. Aperture determines dimmest magnitude.

The clear aperture of the lens, mirror or catadioptric system determines the faintest star that may be recorded with any given film, exposure and focal ratio (f/stop).

For example, a 10 minute exposure of a star on Kodak Tri-X film with a 50mm focal length lens at f/4 will not record stars as faint as the same exposure, on the same film, at f/4 with a seven inch focal length Aero-Ektar. This is because the clear aperture of the Aero-Ektar is 1-3/4 inches, while the lens with a 50mm focal length only has a 1/2 inch aperture. While the larger aperture and camera format are more desirable for photography of large areas of the sky, convenience and portability are factors that motivate people to mount a 35mm camera to their telescopes.

2. Focal ratio determines detail in extended objects.

For extended objects such as nebulae (celestial gas clouds), focal ratio (the ratio of the lens or mirror opening to the focal length) determines the amount of detail which may be recorded using a given film and exposure time. This applies to all background sky fog including light pollution and auroral skyglow.

For example, a fast lens at f/2 will record more nebulosity, more unresolved star clouds (such as the star clouds of Scutum), and sky fog (northern lights), than an f/4 lens at the same exposure. Naturally, a longer focal length f/2 will show more detail in nebulae than a shorter one. This is due to the increase in magnification as focal length increases. One way to increase the

effectiveness of a slow lens in recording extended object detail is to use a higher speed film.

3. Focal length and film grain determine resolution.

Film granularity and lens or mirror focal length determine the fineness of detail in extended objects and star images when using optics having short or moderate focal lengths. At higher magnifications or extremely long focal lengths, atmospheric conditions (seeing) and optical diffraction limits become the primary criteria for detail resolution.

In both cases, star images on the film are always much larger than their infinitely small, theoretical point-of-light sizes.

4. Sky fog affects exposure.

Film does not record fainter star images beyond the exposure limit where sky fog is recorded. Once film begins to record sky fog, added exposure will only record more sky fog which neutralizes the fainter stars (useful exposure has been reached).

On the other hand, more nebulosity may be recorded during a long exposure - even after sky fog has started to record on the film - because the image of an extended object will add to sky fog density where it falls on the film.

Keeping these four principles in mind, let's see what can be done with the various lens and mirror systems available.

Photography of star fields and constellations can be accomplished with a 35mm camera and exposures as short as 10 seconds. Using an f/2 optical system and high speed film (such as Kodak 2475), more stars can be photographed than are seen with the naked eye (see photographs accompanying this article).

The best definition is obtained by stopping down any high speed lens by one f/number. Sharper star images will be recorded and the field of uniform illumination will be improved. From about f/3.5 and up, many lenses may be used at maximum aperture with good definition. For



This color photograph of the winter constellation, Orion, illustrates the pleasing results that may be obtained using commercially available equipment and simple photographic techniques. The camera was a Minolta SRT-101 mounted on a simple camera tripod. A motor driven clock drive was not used to counteract the earth's rotation during this 13 second

exposure on GAF 500 film. Lens opening was f/1.7. Similar results may be obtained by anyone having only a rudimentary knowledge of astronomy and photography. Compare this photograph with those made by John Sanford on pages 30 and 31.

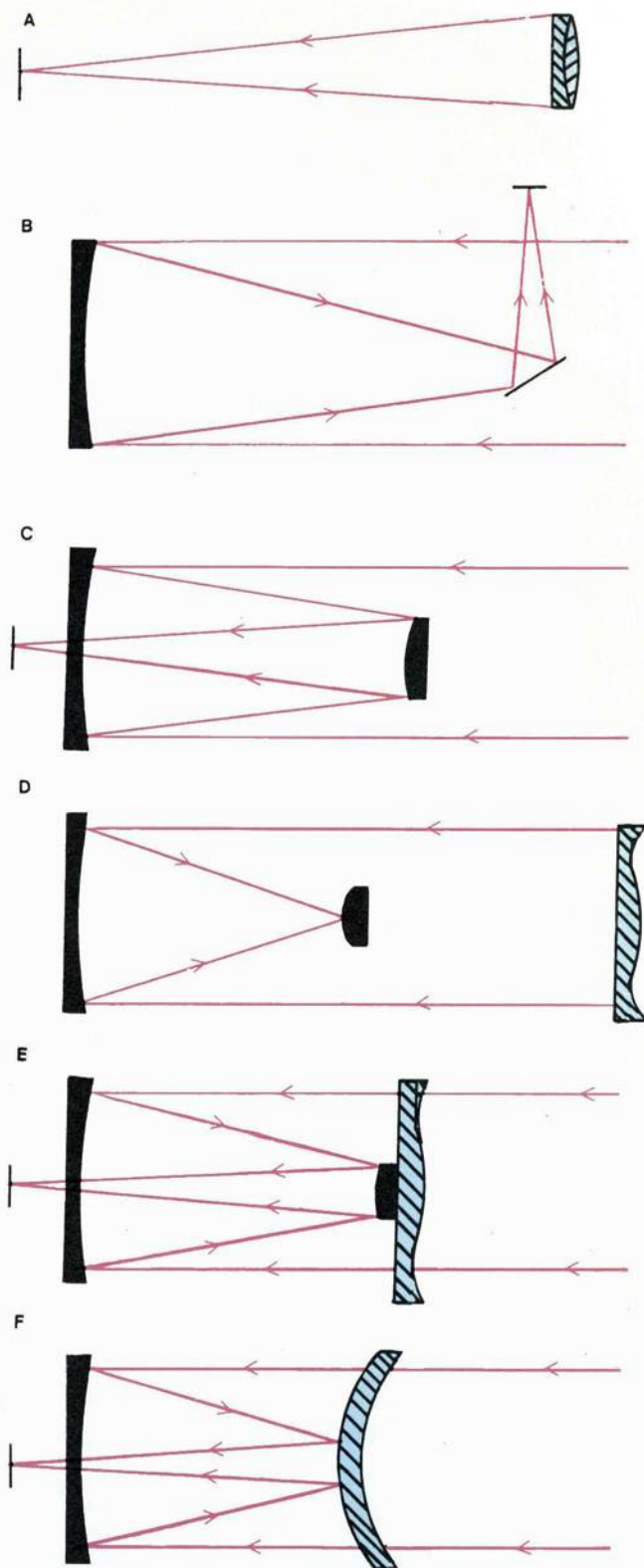
example the f/3.5 Micro-Nikkor, 55mm focal length, is very good wide open but better at f/4! When a camera is mounted on a clock driven equatorial mount, preferably with a guiding telescope, the sharpest star images are possible with maximum definition in extended objects. By guiding the camera to counteract the earth's movement, stars may be recorded which are just about visible with a six or eight inch telescope, and within reasonable exposure time (under 20 minutes).

The subject matter should determine the focal length of lenses used with the "piggy back" method, with about a 500mm focal length being a practical limit when attached to a six or eight inch reflector telescope. A large constellation might dictate use of a 35mm or even 28mm focal length lens, while detail in the Andromeda galaxy, M-31, would require a focal length of 400-500mm. Choosing the correct focal length is important so the subject takes up as large a portion of the film frame as possible. This is especially true with 35mm cameras where graininess is a factor when negatives are enlarged.

Smaller subjects such as star clusters, nebulae and galaxies require more magnification to produce a satisfactory image size. For this purpose, a long focal length telescope mirror or objective lens provides the needed magnification, even at prime focus. One combination many seem to favor is a reflector telescope with a six inch aperture mirror, 24 inches focal length. This combination provides reasonably large scale images, fast speed, and a field of view with good definition. Any reflector telescope with a high quality parabolic mirror, 40 to 80 inches focal length, will produce clear photographic images in a circular area about an inch in diameter.

To make detailed photographs of the sun, moon and planets, more magnification is needed than prime focus provides. However, medium sized Newtonian reflectors which are 10 to 12 inches in aperture with focal ratios of f/7 or f/8 have focal lengths between 70 and 96 inches which produce large images even at prime focus. With these focal lengths, the prime focus image of the sun or moon will just fit into the short dimension of a 35mm camera frame. Longer focal lengths would require a larger film format to register the entire lunar or solar disk.

Compound telescopes which use more than one figured mirror, or a mirror/lens combination (catadioptrics), can be made to cover a much larger field of view than a simple parabolic primary mirror. These include various examples shown in the accompanying diagram.

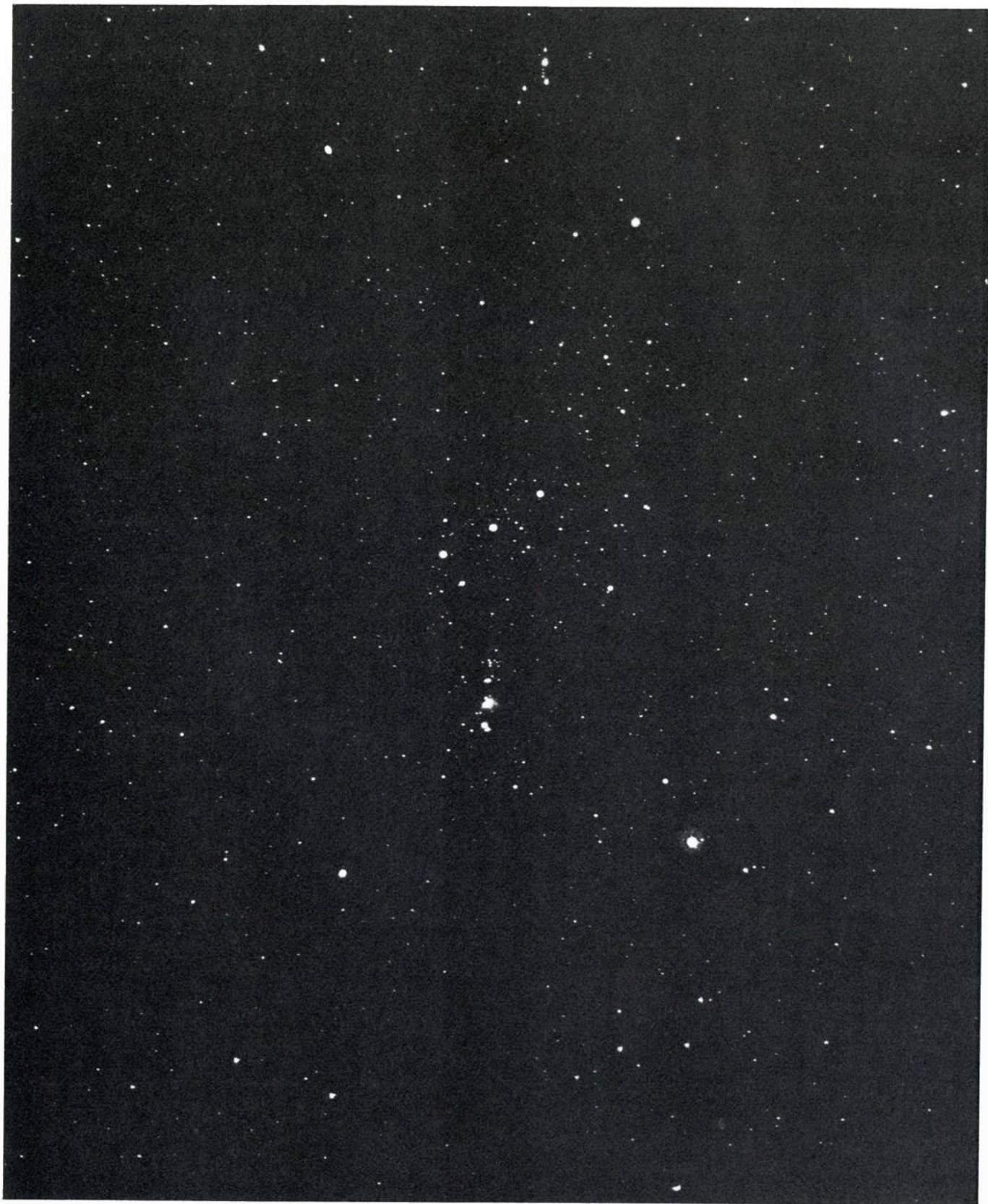


The above schematic drawings show various optical systems suitable for astrophotography. Mirrors are indicated by solid black, lenses are tinted blue, and direction and flow of light is shown by red arrowed lines. A. Achromatic Refractor. B. Simple Newtonian Reflector (see ad on inside cover). C. Classical Cassegrain. D. Classical Schmidt Camera. E. Schmidt Cassegrain (see ad back cover). F. Maksutov.



The comparison photographs of Orion on these two pages show the effect that can be achieved in constellation photography using various equipment and film. Both were 10 second exposures at $f/2.0$ with cameras attached to a

simple camera tripod. Also, both photographs were printed on Agfa Brovira #6 paper. The photograph on the left page was made with a Fujica ST-701 camera having an $f/1.8$ Fujinon, 50 mm lens. Film used was Kodak 2475 developed



in Kodak DK-50. Dimmest star in this photograph is 8.0. On the right page, Orion was photographed with a Nikkormat FT camera having an f/1.4 Nikkor, 50 mm lens. Kodak 103aF spectroscopic film was used and processed in Kodak D-76.

Limiting magnitude on this photograph is 8.7. Examination of the two prints reveals finer grain, better resolution, and more aesthetically appealing star images in the photograph on the right than on the left.



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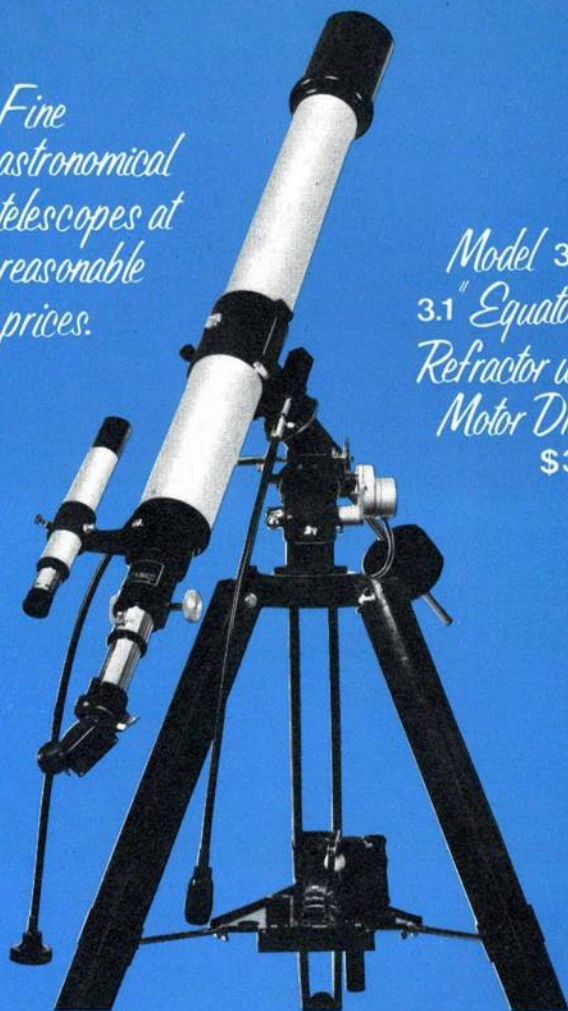
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NASA Photograph

SKY ALMANAC

by

Terence Dickinson

The year's most spectacular display of meteors, the giant multicolored planet Jupiter and comfortable sky watching weather combine to make August 1973 an ideal time to indulge in some outer space exploring from your backyard. If your observing location is amid a forest of streetlights and only a few blocks from a shopping plaza, don't give up yet — there is lots to see if you know what to look for.

Meteors

On any clear night the alert observer will log five to ten meteors per hour. Meteors are often mistakenly called "falling stars", but in reality they have nothing to do with stars. Meteors are tiny bits of stone — so small that 1000 would easily fit in the cupped palm of your hand. Yet each one of them causes that familiar brief but brilliant flash in the night sky as it ends its existence in a 50,000 mile per hour plunge into the top layers of our atmosphere. At that speed friction with the upper air particles vaporizes the average meteor in a half second. It is this vaporization process that produces the brilliant spot of light.

At quite predictable intervals as the earth navigates its annual orbit around the sun, it encounters swarms of meteoric material. These swarms seem to be the remains of disintegrated comets and are located at specific points in the earth's orbit. Like mud puddles on a race track, the meteor swarm is rapidly encountered and soon left behind. The result is a meteor shower lasting a few days at most. This month the most reliable of all predictable meteor displays, known as the Perseids, is due the morning of Sunday, August 12th. Normally the Perseids produce an average of one meteor per minute between midnight and dawn, but this year the nearly full moon will cut down this total substantially. Nevertheless the Perseids are the richest and most reliable of the ten major annual showers. The Perseids are named for the constellation Perseus from which the meteors seem to radiate.

Meteors are always more frequent after midnight than before because the "a.m." part of our planet is facing the same direction as its motion in its orbit. It is similar to the effect one gets during a walk in a heavy snowfall. After a few minutes the front of your coat is plastered with snow (even if there is no wind) while your back is only lightly peppered with flakes. This is of course due to the effect of walking into the flakes. The earth does the same as it pursues its orbit at a consistent 670,000 miles per hour. The side "facing" the meteors is the midnight to dawn side so more meteors are seen during those hours.

Experienced meteor watchers use lawn chairs that adjust to a nearly horizontal position so that almost the entire sky is comfortably in view. Face generally northeast so the moon will be behind you and the constellation Perseus in front of you. Remember to supply yourself with blankets and insect repellent. Try to talk some friends into staying up with you so you can share what at first, to some non-astronomy types, may seem to be an odd activity. Because meteor observing is best done with no telescopic equipment it is an ideal way to introduce sky phenomenon to others.

Despite the fact that one meteor per minute may be observed at the peak of the shower (6 a.m. EDT) the average distance between individual meteors is over 100 miles. So even within a meteor swarm, space is relatively empty. Meteors not quite in the main stream can be seen a few nights before or after August 12th.

Jupiter

Many amateur astronomers consider that giant planet to be the most fascinating object visible in small and medium sized telescopes. Due to a fortunate combination of circumstances, this month is the best time in years for viewing Jupiter.

There can be no mistaking Jupiter even if you are unfamiliar with a single constellation. Anytime between sunset and midnight during

August the great planet appears like a dazzling yellow-white star in the southeast. It is far brighter than any star or planet except Venus; but Venus sets below the western horizon an hour and a half after sunset, whereas Jupiter is plainly visible all night.

On July 30 Jupiter and Earth were in opposition — the point in their orbits when the planets were nearest each other. Although Jupiter was 379 million miles away it still appears larger than any other planet when viewed in telescopes. August — the month after opposition — is a perfect time to turn your telescope to this intriguing world.

Jupiter is a mammoth 88,000 mile wide globe whose volume exceeds that of 100 earths. As it ponderously orbits the sun, taking 12 years for one circuit, it drags along a dozen moons. Like a solar system in miniature, the Jovian satellites have orbital periods ranging from 12 hours to more than two years. Of the 12, four are giants, easily visible in the smallest telescope. Rigidly held binoculars should reveal one or two of them and a 50 mm refractor will show all four unless they are in front or behind the planet itself.

The changing positions of the four big moons are shown in the accompanying chart. Although these satellites have names they are sometimes called the Galilean moons after their discovery by Galileo in 1610 using a very primitive telescope. For convenience they are numbered 1, 2, 3, 4, in order of distance from Jupiter.

Apart from watching the dance of the satellites as they swing from side to side night after night, there are interactions that add some spice to the show. As a satellite passes in front of Jupiter, its shadow is cast on the cloudy banded surface of the great planet. The shadow looks like an ink spot on Jupiter and is easily seen with a four inch telescope. Satellite shadows may be distinguished with a 60 mm refractor but good observing conditions and some experience are helpful when using smaller telescopes. Use about 1 to 1.5 magnifications per millimeter of aperture for best results in shadow hunting. Page 38 has a list of satellite shadow transits this month.

The times listed in the table are Eastern Daylight. For Central Daylight subtract one hour; for Mountain Daylight subtract two hours; for Pacific Daylight subtract three hours. And for Standard time subtract one hour from the appropriate daylight time for your zone.

On the evening of September 1 a transit of Europa's shadow is tabulated, but unlisted is

the shadow of Ganymede which will be on the disk of Jupiter at sunset (visible only from eastern North America) and from 9:23 to 10:26 EDT two shadows will be visible — a relatively rare sight.

A much rarer event occurs when the shadow of one satellite is cast onto another. This only happens when the orbits of the satellites are aligned so that we view them "edge-on", like being table level at a billiard game. Just as the billiard balls would seem to pass back and forth in front of

Satellites of Jupiter

August

11 p.m. E.D.T.

1	21034	• • ● • •	17	10324	• ● ••
2	01234	• • • • •	18	32014	•• ● • •
3	10324	• ● •• •	19	32104	• • • ● •
4	32014	•• ● • •	20	30124	• • ● •• •
5	31204	• • • • •	21	1024	• ● • •
6	34012	•• • • •	22	2403	• • ● •
7	4103	• • • • •	23	403	• • ● •
8	4203	• • • • •	24	41032	• • • • •
9	40123	• • • • •	25	43201	• • • • •
10	41032	• • • • •	26	43210	• • • • •
11	43201	• • • • •	27	43012	• • • • •
12	43120	• • • • •	28	41302	• • • • •
13	34012	• • • • •	29	42013	• • • • •
14	10324	• • • • •	30	14203	• • • • •
15	20134	• • • • •	31	0324	• • • • •
16	0234	• • • • •			

The positions of Jupiter's four brightest moons change hourly and daily, and make an interesting sight to view even in a small telescope or high powered binoculars. Shown above is the approximate appearance of Jupiter and its satellites as they might look in a small telescope at 11 p.m., EDT. First column on the left shows the date. Second column of numbers identifies the moons and their position relative to Jupiter's disk. (1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto, and 0 = Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions.

SUN

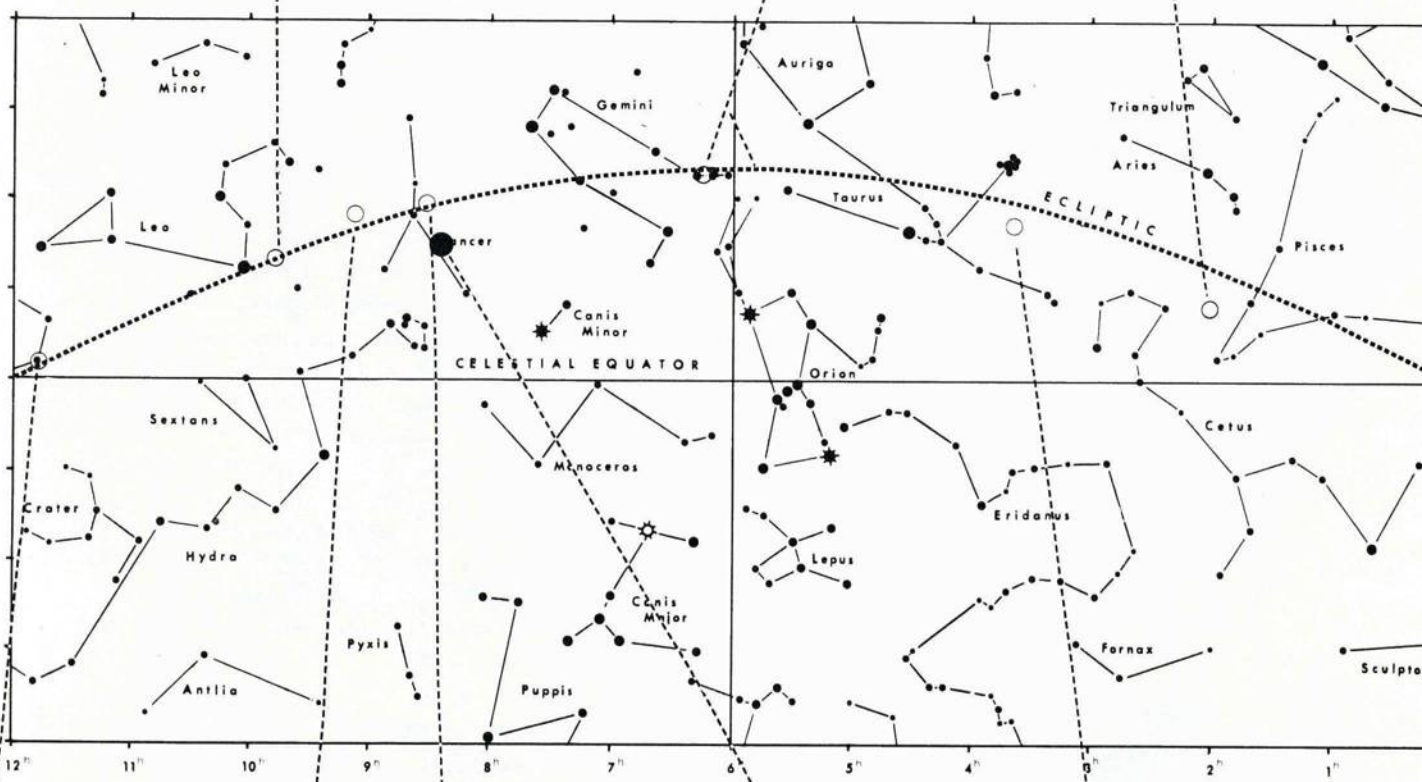
August	1	16
R.A.	8 ^h 44 ^m	9 ^h 41 ^m
DEC.	+18° 07'	+13° 51'
DIST.	1.015 A.U.	1.013 A.U.
D DIA.	31' 32"	31' 38"

SATURN

August	1	16
R.A.	6 ^h 00 ^m	6 ^h 06 ^m
DEC.	+22° 23'	+22° 23'
DIST.	9.787 A.U.	9.612 A.U.
DIA.	15.24"	15.52"
MAG.	0.3	0.3

MARS

August	1	16
R.A.	1 ^h 36 ^m	2 ^h 02 ^m
DEC.	+6° 24'	+8° 42'
DIST.	0.722 A.U.	0.643 A.U.
DIA.	12.9"	14.5"
MAG.	-0.6	-0.9



MERCURY

August	1	16
R.A.	7 ^h 37 ^m	8 ^h 35 ^m
DEC.	+18° 04'	+19° 00'
DIST.	0.717 A.U.	1.081 A.U.
DIA.	9.7"	6.2"
MAG.	+1.4	-0.6

NEW MOON

July 29, 12:59 p.m., EDT	
R.A.	8 ^h 33 ^m
DEC.	+16° 11'

VESTA

August	1	16
R.A.	8 ^h 35 ^m	9 ^h 03 ^m
DEC.	+20° 36'	+18° 59'
DIST.	3.492 A.U.	3.453 A.U.
DIA.		
MAG.	+8.9	+8.8

VENUS

August	1	16
R.A.	10 ^h 42 ^m	11 ^h 48 ^m
DEC.	+9° 45'	+2° 18'
DIST.	1.397 A.U.	1.307 A.U.
DIA.	12.0"	12.7"
MAG.	-3.4	-3.4

THIRD QUARTER

August 21, 4:22 a.m., EDT	
R.A.	3 ^h 40 ^m
DEC.	+22° 49'

FULL MOON

August 13, 8:17 p.m., EDT
R.A. 21h 29m
DEC. -11° 06'



NEPTUNE

August	1	16
R.A.	16h 12m	16h 12m
DEC.	-19° 29'	-19° 29'
DIST.	29.850 A.U.	30.089 A.U.
DIA.	2.44"	2.44"
MAG.	+5.7	+7.7



URANUS

August	1	16
R.A.	13h 13m	13h 15m
DEC.	-7° 04'	-7° 17'
DIST.	18.715 A.U.	18.941 A.U.
DIA.	3.66"	3.62"
MAG.	+5.7	+5.7



JUNO

August	1	16
R.A.	16h 28m	16h 30m
DEC.	-5° 39'	-6° 51'
DIST.	2.655 A.U.	2.830 A.U.
DIA.	+11	+11.1



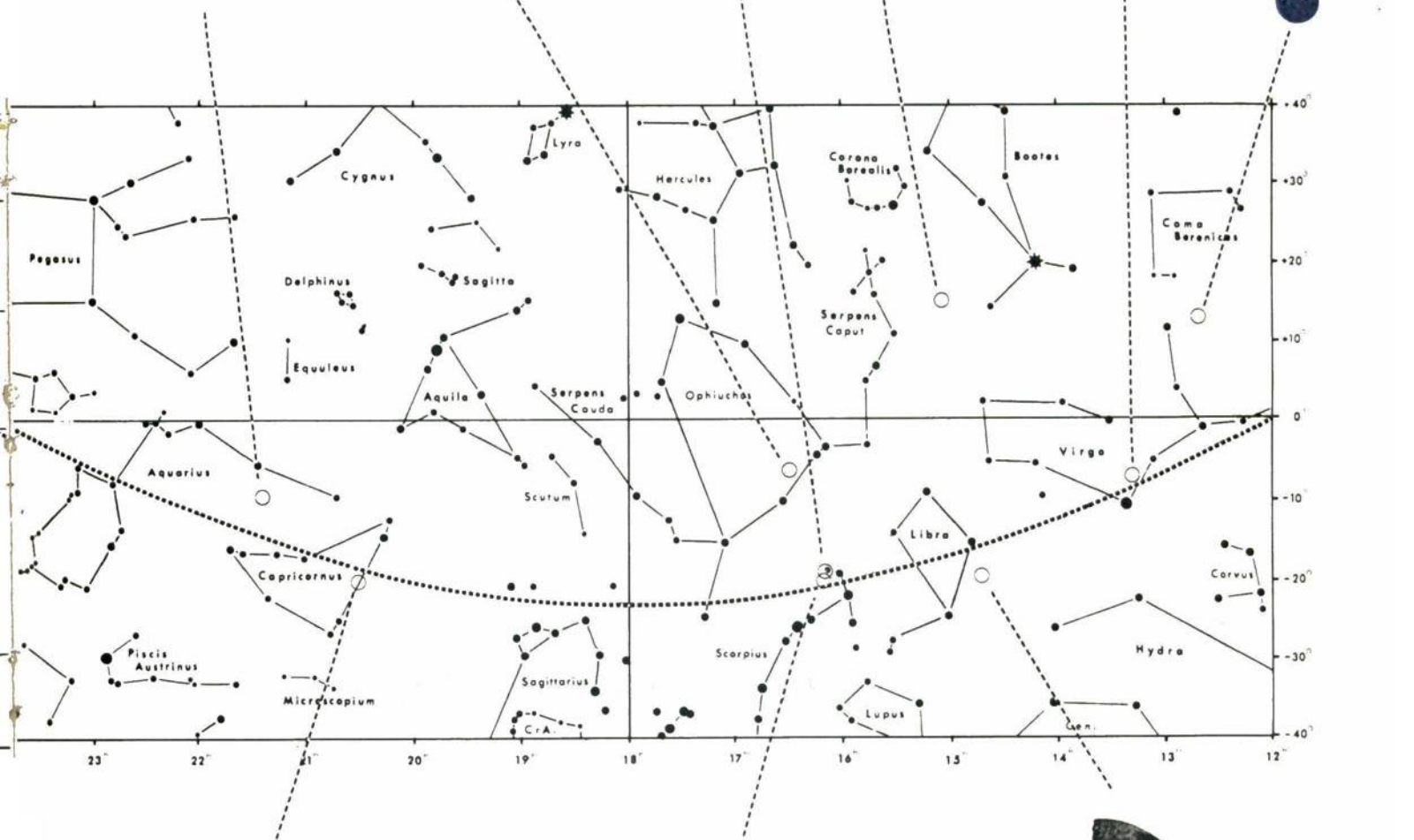
PALLAS

August	1	16
R.A.	14h 48m	15h 00m
DEC.	+18° 51'	+16° 21'
DIST.	2.843 A.U.	3.039 A.U.
DIA.	+9.7	+9.8



PLUTO

August	1	16
R.A.	12h 33m	12h 35m
DEC.	+14° 05'	+13° 50'
DIST.	31.616 A.U.	31.752 A.U.
DIA.	+14	+14



CERES

August	1	16
R.A.	16h 07m	16h 13m
DEC.	-21° 30'	-22° 22'
DIST.	2.242 A.U.	2.443 A.U.
DIA.	+8.1	+8.4



JUPITER

August	1	16
R.A.	20h 38m	20h 31m
DEC.	-19° 14'	-19° 44'
DIST.	4.078 A.U.	4.115 A.U.
DIA.	45.06"	44.66"
MAG.	-2.4	-2.3



FIRST QUARTER

August 5,	4:27 p.m., EDT	14h 37m
R.A.		-19° 47'
DEC.		



This chart shows the positions of the sun, moon, planets and brighter asteroids as they appear against the background of the zodiac. Positions on the chart are for the 16th of the current month with additional ephemerides for the 1st next to the appropriate object. To see which zodiacal constellations are visible during the current month, refer to Star Dome.

each other during the progress of the game, the satellites of Jupiter pass in front of each other as they circuit the planet. But this circumstance only exists for two years out of twelve. The rest of the time we see the satellites either from slightly above or below.

Even a small telescope will reveal the presence of the shadow since the satellite being covered will become fainter. There are three occasions during the next few weeks when the shadow of one satellite will fall on another. On August 20 between 2:45 and 2:55 a.m. EDT the shadow of Io (I) will fall on Europa (II). Io's shadow will cover about 60 percent of Europa at the midpoint of the eclipse. A similar event occurs on September 6 between 9:15 and 9:30 EDT. On September 17 Ganymede's (III) shadow will almost entirely cover Europa. The event will last about half an hour — the shadow first touching Europa at about 3:15 a.m. EDT. Observers with eight inch or larger telescopes may see the actual shadow on the tiny disk of Europa if atmospheric conditions are excellent. The identity of each satellite can be established by use of the satellite configuration chart on this page.

All this activity among the satellites of Jupiter is complemented by equally fascinating detail on the face of the giant itself. Its great planetary bulk is spinning in less than 10 hours — faster than any other planet. This rapid rotation combined with a rich mixture of ammonia clouds in a hydrogen-methane atmosphere produces a multi-colored banded globe that changes from hour to

hour. Even a 60 mm refractor will show some of the major rusty colored belts especially in the equatorial zones. The famous Great Red Spot is visible in a 60 mm refractor and larger instruments almost always will reveal it if that side of Jupiter is facing earthward. Larger telescopes reveal more detail until eight inch or larger telescopes reward the viewer with a wealth of intricate detail in and between the belts.

Just as obvious as the belts is the oval shape of the planet. Actually it is an oblate spheroid with a polar diameter about eight percent less than the equatorial diameter — a result of the rapid rotation and thick atmosphere. In apparent dimensions Jupiter is 48 seconds of arc in equatorial diameter and 45 seconds of arc in polar diameter on August 1. These dimensions will reduce to 46 and 43 seconds respectively by month's end as Jupiter's distance increases from 379 to 393 million miles from earth.

Venus

Low in the west after sunset, Venus is a dazzling evening "star". It sets about an hour and a half after the sun. At magnitude -3.4 it is 18 times brighter than Arcturus — the second brightest star in the summer sky. This month Venus is a disappointment in any telescope. Because it is nearly at its maximum distance from us, Venus appears quite small. (Distance decreases from 157 to 136 million miles during the month.) Since it is on the far side of its orbit we view an 85 percent illuminated disk on August 1 decreasing to 77 percent by the 31st. The apparent diameter in-

SATELLITE SHADOWS ON JUPITER

Satellite	Date	Begins	Ends
I	Aug. 1-2	11:16 p.m.	1:35 a.m.
III	4	2:45 a.m.	6:22 a.m.
II	7-8	12:21 a.m.	3:11 a.m.
I	9	1:11 a.m.	3:30 a.m.
II	15	2:56 a.m.	5:45 a.m.
I	16	3:06 a.m.	5:24 a.m.
I	17	9:35 p.m.	11:53 p.m.
IV	22-23	12:24 a.m.	5:07 a.m.
I	24	11:30 p.m.	1:48 a.m.
I	Sept. 1	1:26 a.m.	3:44 a.m.
II	1	9:23 p.m.	12:12 a.m.

creases from 12 to 14 seconds of arc during the month.

Try observing Venus as soon as possible after sunset to avoid atmospheric turbulence near the horizon. See if you can detect the phase or does the tiny brilliant white disk appear circular?

Mercury

A much more challenging object than Venus, Mercury is fainter, and its tight little orbit keeps it so close to the sun that it is elusive and sometimes frustrating to observe. Being the smallest planet adds to its reputation as a difficult object to observe. Some of this pessimism is undeserved because Mercury is actually bright enough to be easily recognizable, often exceeding Arcturus in brightness.

This month Mercury swings to the west of the sun and consequently is an early morning object. Watch for it just below Castor and Pollux, in the constellation Gemini, about 45 minutes before sunrise from the 4th to the 16th. Unlike Venus, Mercury very rapidly runs through its phases. On the 4th it appears 24 percent illuminated (crescent phase) but by the 16th we will see 69 percent of the illuminated side of the planet. This rapid change of phase would be fascinating to watch but Mercury's tiny apparent size (nine seconds of arc on the 4th and six seconds on the 16th) makes the phases difficult to resolve in telescopes smaller than three inch refractors or four inch reflectors.

Mars

Earth is overtaking the more slowly moving Mars as their separation decreases from 67 million to 53 million miles during August. The brightness of the red planet increases from magnitude -0.6 to -1.2 by month's end, making it brighter than any planet or star except Venus, Jupiter and Sirius.

The reddish planet can be seen after midnight in the east, far brighter than the stars of the surrounding faint constellations, Cetus and Aries. Telescopically, Mars increases in apparent size from 13 to 17 seconds of arc during August. This is large enough for users of moderate size telescopes (five inch or larger) to begin to detect some of the dark surface features whose nature is still unknown. More about Mars next month.

Saturn

The ringed planet has moved into the constellation Gemini where it will be for the next two years. Early morning observers — perhaps on the watch for Mercury — can find Saturn directly north of Orion. The rings are fully open for inspection in a two inch or larger telescope.

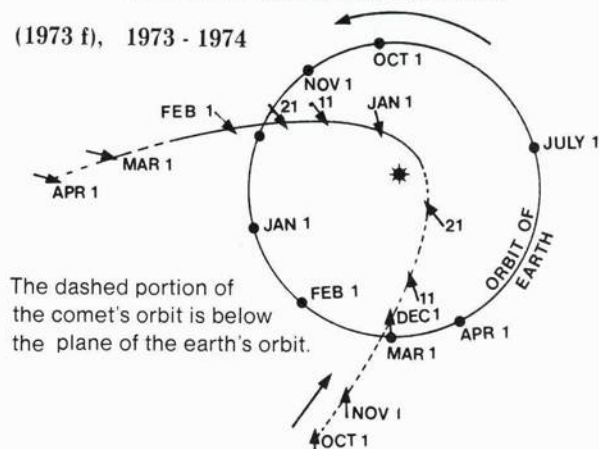
Comets

Later this year a recently discovered comet will sweep by the sun in a path that should give earthlings their best view of a comet since the last pass of Halley's Comet in 1910. According to preliminary calculations from the Smithsonian Astrophysical Observatory the comet will be brightest in December and January when it is expected to be easily visible to the unaided eye.

Comet Kohoutek, as it is now officially designated, was discovered in the constellation Hydra on March 7 by Lubos Kohoutek at Hamburg Observatory, West Germany. (Comets are usually named after their discoverer.)

ORBIT OF COMET KOHOUTEK

(1973 f), 1973 - 1974



The dashed portion of the comet's orbit is below the plane of the earth's orbit.

Kohoutek was searching for asteroids — those tiny planets that orbit between Mars and Jupiter. On two of the photographs he noticed a faint fuzzy spot that proved to be a comet racing toward our part of the solar system from the vicinity of Jupiter's orbit.

The new comet is much larger than average, having a core of frozen gases possibly 20 miles in diameter. A cloud of hydrogen surrounds the core giving the fuzzy appearance that Kohoutek noticed.

When the comet nears the sun in December, solar radiation will melt part of the frozen core. The gases so produced will be forced away from the nucleus by the pressure of the sun's radiation, producing a spectacular streaming tail that could reach several million miles into space.

A similar comet known as Ikeya-Seki passed by the sun in 1965. The comet was an impressive sight from some parts of the world but those above 40 degrees north latitude hardly got a glimpse of it. However Comet Kohoutek should be easily seen from almost everywhere. Watch this column for further details.

R AQUILAE

by

R. Newton Mayall

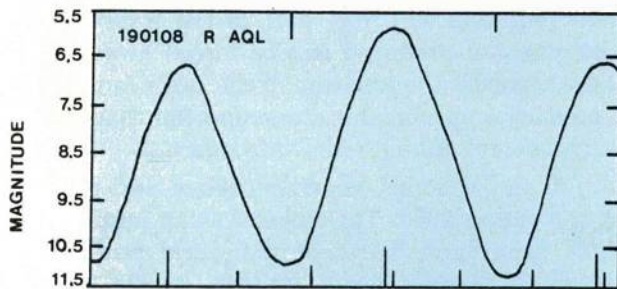
Variable Stars

Some variables have a very interesting history, and R Aquilae is one. It has been under constant observation since Argelander (1799-1875) announced its variation during the course of his work on the **Durchmusterung** catalog in 1856. Also, it is of particular interest because it is one of the few variables whose period has shortened from 350 days to about 300 days, in 80 years. The question is, will its period continue to shorten or will it increase? And when? Obviously this star has intrigued many observers.

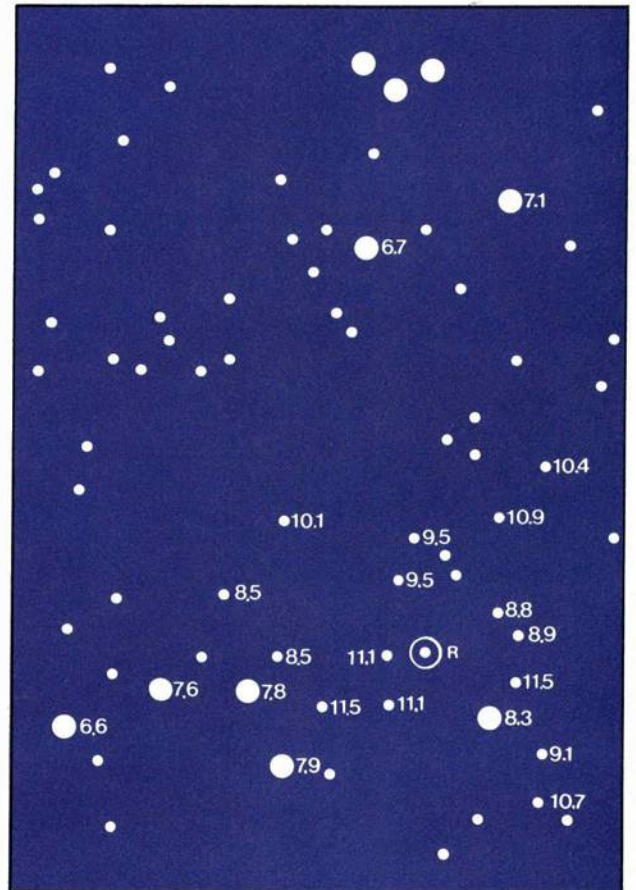
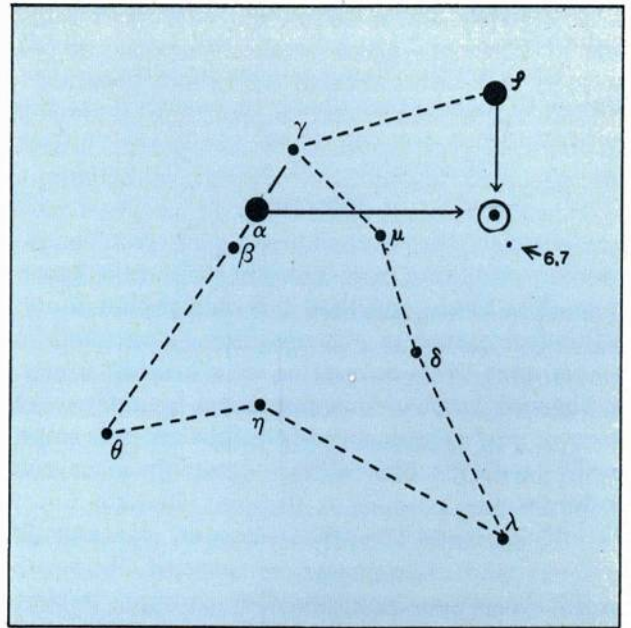
Aquila's dominant star is Altair, the middle one of three stars which are prominent in the constellation. Locate Zeta Aquila about 15 degrees northwest of Altair. R Aquilae will be found at the intersection of a line due west of Altair and a line due south from Zeta. It can be readily recognized by its red color which intensifies as it grows fainter.

R Aquilae has a magnitude range from 6.0-11.4 and a period of 293 days, at present. The constellation culminates at 10 p.m. about August 30th. Although the period is constant at the present time, there is a difference or irregularity in the magnitude range as shown in the accompanying light curve covering 700 days. The upper tick marks refer to the minima and the lower marks refer to the maxima. It is surely a most interesting star to observe.

There are only a few long period variables whose declines in period are known. The best known are R Hydrae and R Centauri. The cause of the slowly changing period of R Aquilae is not definitely known but it is thought that the internal structure of the star is undergoing a change.



Light curve of R Aquilae showing variation in range of magnitude in 700 days. Small tick marks at bottom are 100 days apart.



The upper chart shows the constellation Aquila as it appears in the sky (see Star Dome) and the general location of sixth magnitude R Aquilae. The lower map provides a close-up view of comparison stars surrounding the variable. Numbers to the right of each star indicate its magnitude. R. Aquilae is circled and the chart is inverted for use with a reflecting telescope or refractor without erecting prism. (Telescopes generally provide an "upside down" view of the sky.)



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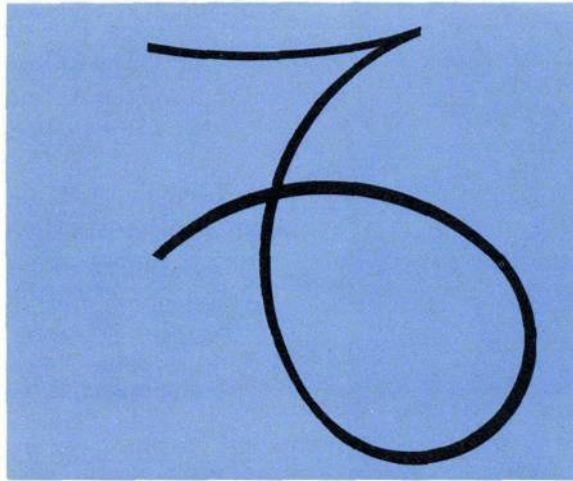
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Capricornus



by

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With summer's end at hand, constellations rising in the East herald the approach of autumn.

One such Zodiacal constellation - Capricornus - stands well placed for observation in the southeastern sky during August. And while its third and fourth magnitude stars are vastly outshone by Sagittarius preceding it, the gentle group of stars is compact enough to easily recognize the constellation's inverted triangular shape.

Capricornus, 11th constellation of the Zodiac, contains only one Messier object - the only nebula or star cluster to merit plotting in **Norton's Star Atlas**. Despite this apparent poverty, Messier 30,

a rather unusual appearing globular star cluster, and several fine double stars make Capricornus well worth observing (see table of objects).

While collecting data on these objects, an excerpt came to mind which epitomizes the philosophy of **ASTRONOMY** magazine. In an article entitled "The Value of Science", from **Frontiers Of Science**, author Richard P. Feynman describes the awe and mystery that are an intrinsic part of the "grand adventure" of scientific inquiry.

"And yet," says Feynman, "it is true that few unscientific people have this particular type of religious experience. Our poets do not write about it; our artists do not try to portray this remark-

able thing. I don't know why. Is nobody inspired by our present picture of the universe? The value of science remains unsung by singers, so you are reduced to hearing - not a song or poem, but an evening lecture about it. This is not yet a scientific age."

Perhaps much too often in astronomy we tend to speak in statistical terms, and not in poem or song. For example, compare these two different descriptions of the same globular cluster in Capricornus - M-30.

First, from Neale E. Howard's **Telescope Handbook and Star Atlas**:

"A small globular about four degrees east of Zeta Capricorni, near an eighth magnitude star. It is resolvable in a six inch reflector, and appears to have streamers of stars to the north and west."

In contrast, we find this second quote by Smyth in Webb's **Celestial Objects for Common Telescopes**:

"What an immensity of space is indicated! Can such an arrangement be intended, as a bungling spouter of the hour insists, for a mere appendage to the speck of a world on which we dwell, to soften the darkness of its petty midnight? ...No imagination can fill up the picture, of which the visual organs afford the dim outline."

Howard's description is certainly a useful one, the kind we've come to expect, while Smyth's is quite unusual and a bit melodramatic. Nevertheless, perhaps today too much emphasis is placed on technical information - sizes, positions, magnitudes - and not enough on our aesthetic reactions to what we are seeing.

Hopefully, the statistical information in this department each month will prove beneficial. But most important, it is hoped that when you go out to observe the beautiful objects in our universe, you'll take a friend and try asking him - not just telling him - what it is that he sees.

TABLE OF OBJECTS IN CAPRICORNUS

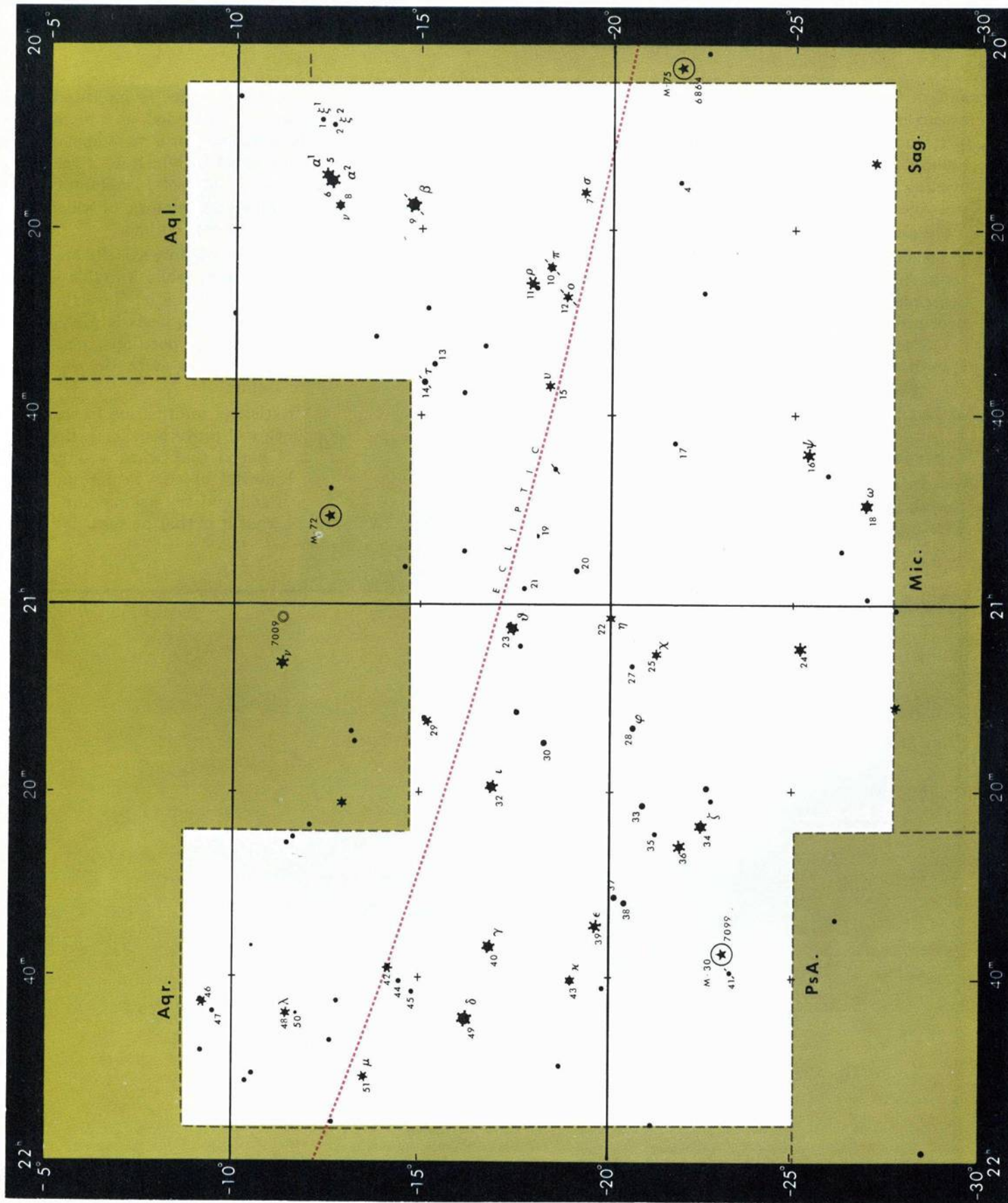
Double Stars

<u>Star</u>	<u>R.A.</u>	<u>Dec.</u>	<u>Magnitudes</u>	<u>Sep.</u>	<u>Colors</u>
α^1	20h 16m	-12°37'	4.6 - 9.0	45.0"	yellow - yellow
α^2	20 16	-12 39	3.8 - 10.6	7.1"	yellow - yellow
π	20 26	-18 19	5.2 - 8.5	3.2"	yellow-blue
ρ	20 27	-17 56	5.0 - 10.0	1.0"	yellow - purple
σ	20 28	-18 42	6.1 - 6.6	21.9"	white - blue

* α^1 and α^2 are a naked eye pair, at a separation of 376".

Messier Objects

<u>Object</u>	<u>R.A.</u>	<u>Dec.</u>	<u>Mag.</u>	<u>Size</u>	<u>Class</u>
M-30	21 39	-23°20'	8	5.7	V



Stellar Magnitudes

-1	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6 and fainter

Diffuse Nebula

Double stars Variable stars

Galaxies

Planetary Nebula

Open Star Clusters

Globular Clusters



Capricornus, photographed on Kodak High Speed Ektachrome film, was processed to ASA-400. This 13 second

exposure was made with a Minolta SRT-101 camera having a Rokkor, 55mm lens at $f/1.7$.



BIOGRAPHY

Raymond G. Couthie — Mr. Couthie, cartographer and western regional editor of *ASTRONOMY*, prepares all the charts appearing in *Constellation Close-Up*, *Sky Almanac* and *Star Dome*.

An engineering graduate of Los Angeles City College, he has also done extension work in astronomy under Dr. George Abell at the University of California — Los Angeles.

In 1935, at age 19, Mr. Couthie designed and built the rocket ships used in the "Flash Gordon" series filmed at Universal Studios in California.

He founded the Polaris Astronomical Society in 1959, and in 1965 the Polaris Observatory Association for more serious amateurs. He currently is a representative for both groups to the Western Amateur Astronomers.

In 1963 his *Deep Sky Catalog and Star Atlas* was published. In addition to designing and testing astronomical equipment, he has produced many astrophotographs and researched various types of film and their processing.

Mr. Couthie is the 1973 nominee for the G. Bruce Blair award which is presented annually by the Western Amateur Astronomers to a person who has made a significant contribution to amateur astronomy.

Terence Dickinson — Mr. Dickinson is Assistant Director of the Strasenburgh Planetarium, Rochester Museum and Science Centre. He was previously on the staff of the McLaughlin Planetarium at the University of Toronto in Canada.

Born in Canada, Mr. Dickinson first became interested in astronomy at the age of nine when his father took him to visit the Dunlap Observatory near Toronto. His knowledge broadened and at age 17, he presented the first of a long series of lectures to the Royal Astronomical Society of Canada.

Mr. Dickinson has been a consultant for space science programming for the Canadian Broadcasting Corp. and Canadian Television Network. His recent book, *Exploring the Moon and the Solar System*, is used in Canadian schools. His scientific articles have also appeared in numerous magazines, journals and newspapers.

John G. Harmon — Mr. Harmon is assistant to the director of the Manfred Olson Planetarium at the University of Wisconsin — Milwaukee, Milwaukee, Wisc. He has worked for the planetarium since 1968 — first as an undergraduate teaching assistant, and now as a Planetarium Specialist.

Mr. Harmon's current projects include the

design and building of special effects projectors for the planetarium, and the restoration of a five inch refractor telescope built in 1870 by telescope designer Alvin Clarke.

R. Newton Mayall — Mr. Mayall is an engineer and noted amateur astronomer. His wife, Margaret, is a professional astronomer and Director of the American Association of Variable Star Observers (AAVSO).

Together and singly, the Mayalls have written many books on astronomy and related subjects. Mr. Mayall has also contributed to several encyclopedias and national magazines. He is a member of the AAVSO and the Royal Astronomical Society of Canada.

Jay M. Pasachoff — Dr. Pasachoff is Chairman of the Astronomy Department and Director of the Hopkins Observatory at Williams College, Williamstown, Mass. He was previously employed at the Hale Observatories (formerly called Mount Wilson and Palomar Observatories) and Caltech.

A Harvard alumnus, Dr. Pasachoff has worked consistently on solar physics — concentrating on the dynamics and radiation processes in the solar chromosphere — and is interested in stellar spectroscopy.

John R. Sanford — Mr. Sanford is an assistant professor in the photography department at Orange Coast College in Costa Mesa, Calif.

After graduating in 1961 with a degree in anthropology from Cornell University, he entered the Army. While in the service he was trained in photography and photo lab operations, and was a member of the first photo team to go to Vietnam in 1962. Subsequent to his discharge, Mr. Sanford worked for I.B.M. doing photographic and motion picture work, returned to Vietnam as a civilian tech-rep for a mobile photo lab company, and later worked for Lockheed Missile and Space Co. He eventually returned to school and received an M.A. in Creative Arts Interdisciplinary Studies in 1970.

Wm. Bruce Weaver, Ph.D. — Dr. Weaver is currently an astronomer with the Monterey Institute for Research in Astronomy (MIRA), a non-profit corporation in Carmel Valley, Calif.

Studying astronomy and astrophysics, he received his B.S. from the University of Arizona in 1968, and his Ph.D. from Case Western Reserve University in 1972.

Dr. Weaver's primary research interests are observational: stellar spectroscopy and photometry. Most of his time is spent teaching and helping to establish the new observatory.



WANTED

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ASTRONOMY is seeking articles/photographs from free lance writers/photographers in all fields of professional and amateur astronomy. Editorial contributions being sought fall into four main categories:

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3. Photographs, preferably in color whenever possible, but black and white are acceptable. For color, transparencies are preferred over prints, made with as large a film print as possible. We would like to receive 4 x 5 transparencies, but accept 35mm. Black and white prints should be on glossy paper, 5 x 7 inches or larger. Photos are used with accompanying articles, singly in special "Star Gallery" photo spreads and to illustrate articles by other authors.

4. Department stories, 1,500 to 2,500 words in length, especially for Equipment Atlas, Gazer's Gazette and Photography in Astronomy. Articles for Equipment Atlas should focus on eye-pieces, telescopes, and other equipment used to study the sky. Without becoming too technical, optical theory might be introduced through this department. Gazer's Gazette should focus on all

aspects of observational astronomy. Might one of our readers send in an illustrated article on how to read a star atlas? Photography in Astronomy is self explanatory — send us your best color (and B & W) astrophotos, as well as articles on effective or novel methods of astrophotography.

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Include a bibliography on a separate sheet, but do not footnote these sources in the article.

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Background Photo — The Rosette Nebula, Celestron 5½-in. Schmidt Camera

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